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CONTENTS.

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RECORDS

OF

THE GEOLOGICAL SURVEY OF INDIA.

Part 3.] 1934 [September

NOTICE.

As Part 3 contains the Mineral Production during 1933, its publication has been expedited. Part 2 will be published later.

PAGE.

I. INTRODUCTION.

THE method of classification adopted in the first Review of Mineral Production published in these *Records* (Vol. XXXII, 1905), although admittedly not entirely satisfactory, is still the best that can be devised under present conditions. As the methods of collecting the returns become more precise, and the machinery employed for the purpose more efficient, the number of minerals included in Class I—for which approximately trustworthy annual returns are available—increases, and it is hoped that the minerals of Class II—for which regularly recurring and full particulars cannot be procured—will in time be reduced to a very small number. In the case of minerals still exploited chiefly by primitive Indian methods and thus forming the basis of an industry carried on by a large number of persons each working independently and on a very small scale, the collection of reliable statistics is impossible; the total error from year to year, however, is characterised by some degree of constancy, and the figures obtained may be accepted as a fairly reliable index to the general trend of the industry. In the case of gold, the small indigenous alluvial industry contributes such an insignificant portion to the total outturn that the error from this source may be regarded as negligible.

The average value of the Indian rupee during the year 1933 was 1*s.* $6\frac{1}{32}$*d.*; the highest value reached was 1*s.* $6\frac{5}{32}$*d.* and the lowest 1*s.* $5\frac{13}{16}$*d.* The values for 1933 shown in the tables are given on the basis of 1*s.* $6\frac{1}{32}$*d.* to the rupee; for ease of calculation, £1 has been taken to be equivalent to Rs. 13·3 instead of Rs. 13·31.

Table 1 shows the total value of minerals for which returns of production are available for the years 1932 and 1933. The average figure for the quinquennium, 1919-23, was £25,194,123. In the following year, 1924, there was an apparent increase of over £3,500,000; this was, in part, however, due to the higher average value of the rupee during that year. Since 1924, there has been a steady decline, which persisted down to the year 1928, for which the value was £21,888,528. There was an arrest in this decline in 1929, which showed an increase in total value to £22,328,686 or about 2 per cent. over that of 1928. In 1930, however, the decline was resumed and the total value of the production fell by over £2,500,000 to £19,750,233, this continuing in 1931, by over

TABLE 1.—*Total value of Minerals for which returns of production are available for the years 1932 and 1933.*

——	1932.	1933.	Increase.	Decrease.	Variation per cent.
	£	£	£	£	
Petroleum . . .	3,818,875	4,707,959	889,084	..	+23·3
Coal	5,120,045	4,600,457	..	519,588	—10·1
Gold	1,906,123	2,078,201	172,078	..	+9·0
Salt	898,754	859,012	..	39,742	—4·4
Lead and lead-ore (*a*) .	820,109	851,320	31,211	..	+3·8
Building materials .	686,811	800,012	113,201	..	+16·5
Tin-ore . . .	339,097	533,082	193,985	..	+57·2
Silver. . . .	471,557	497,213	25,656	..	+5·4
Copper-ore and matte .	338,156	392,251	54,095	..	+16·1
Mica (*b*) . . .	251,800	307,671	55,871	..	+22·1
Zinc concentrates .	113,481	231,800	118,319	..	+104·2
Iron-ore . . .	294,720	187,813	..	106,907	—36·2
Manganese-ore (*c*) .	140,022	123,171	..	16,851	—12·0
Saltpetre (*b*) . .	92,272	117,136	24,864	..	+26·9
Tungsten-ore . .	52,921	81,551	28,630	..	+54·0
Nickel-speiss . .	77,269	77,333	64	..	+0·09
Ilmenite . . .	58,134	43,384	..	14,750	—25·4
Antimonial lead . .	6,627	17,997	11,370	..	+171·6
Chromite . . .	20,727	16,785	..	3,942	—19·0
Clays . . .	19,451	16,382	..	3,069	—15·7
Steatite . . .	9,736	13,757	4,021	..	+41·3
Jadeite (*b*) . . .	28,359	13,513	..	14,846	—52·3
Refractory materials .	10,103	8,037	..	2,066	—20·4
Magnesite . . .	5,470	7,344	1,874	..	+34·3
Ruby, sapphire and spinel.	..	6,961	6,961	..	
Fuller's earth . .	3,405	5,845	2,440	..	+71·7
Monazite . . .	6,147	(*d*)	..	..	..
Gypsum . . .	6,491	4,975	..	1,516	—23·4
Diamonds . . .	5,428	4,789	..	639	—11·7
Ochres . . .	2,489	4,578	2,089	..	+83·9
Barytes . . .	2,209	3,122	913	..	+41·4
Zircon . . .	3,905	3,118	..	787	—20·7
Beryl . . .	397	546	149	..	+37·6
Felspar . . .	330	442	112	..	+34·0
Bauxite . . .	656	237	..	419	—63·9
Garnet . . .	28	222	194	..	+693·0
Amber . . .	146	113	..	33	—22·6
Apatite . . .	81	28	..	53	—65·4
Bismuth . . .	4	12	8	..	+200·0
TOTAL .	15,612,235	16,618,069	1,737,189	725,208	6·4
			$\underbrace{\qquad\qquad}_{+1,011,981}$		

(*a*) Excludes antimonial lead. (*b*) Export values. (*c*) Export f.o.b. values.
(*d*) Reliable figures not received.

£2,000,000 to £17,739,994, and again in 1932 by over £2,000,000 to £15,612,235. In 1933, however, the tide has turned and the total value of the output increased by more than £1,000,000 to £16,,618,069. Of each of the fourteen minerals with a value of over £100,000 annually, increases are shown by zinc concentrates (104·2 per cent.), tin-ore (57·2 per cent.), saltpetre (26·9 per cent.), petroleum (23·3 per cent.), mica (22·1 per cent.), building materials (16·5 per cent.), copper-ore and matte (16·1 per cent.), gold (9·0 per cent.), silver (5·4 per cent.), and lead and lead-ore (3·8 per cent.), whilst decreases are shown by iron-ore (36·2 per cent.), manganese-ore (12·0 per cent.), coal (10·1 per cent.), and salt (4·4 per cent.). For the first time petroleum heads the list of values as the most important mineral. Otherwise the most important changes are the further decreases in the value of the output of coal and manganese-ore, India's two most distressed mineral industries. Amongst less important minerals the largest increases in value are shown by tungsten-ore and antimonial lead, steatite, ochres and magnesite, whilst the most important decreases are shown by jadeite, ilmenite, chromite, refractory materials and clays.

An increase or decrease in value does not always correspond to a similar variation in output, and cannot, therefore, be regarded as an infallible indication of the state of an industry. But in 1933, in all cases, with nine exceptions, an increase or decrease of value accompanied an increase or decrease of the quantity of production. The exceptions were diamonds, manganese-ore, salt, clays refractory materials and zircon, in which increases in output were accompanied by decreases in total value; and petroleum, nickel-speiss and amber, in which decreases in quantity were accompanied by increases in value, the disparity in the case of petroleum being especially marked, for a small decrease in quantity was accompanied by a large increase in value.

It is interesting to compare the changes in the figures of total value recorded in Table 1 with the variations in the average annual value of the leading metals and ores as summarised in Table 2. In 1931 all the metals and ores given in this table showed a fall in price except gold, in the price of which there was a substantial rise. In 1932 there was a very large rise in the price of gold, and in addition a partial recovery in the price of spelter, tin and silver. In 1933 there were small falls in the price of lead and chromite; the prices of steel rails, ferro-manganese and manganese-ore were

stationary; whilst the prices of other metals and ores rose, the largest rise being that of tin.

The number of mineral concessions granted during the year under review amounted to 406 against 327 in the preceding year. Of these 24 were quarry leases, 325 were prospecting licenses, and 57 were mining leases. This small total compared with the figure (714 mineral concessions) for 1927 is an index of the decreased prospecting and private geological enterprise that accompanies a period of depression. In the same way the increase in 1933 compared with 1932 should be an index of the turn of the tide.

TABLE 2.—*Average prices in the United Kingdom of Principal Metals and Ores during the years 1932 and 1933.*

—	1932. £ per ton.	1933. £ per ton.
Metals—		
Copper, standard	31·73	32·38
Lead, pig, soft foreign	12·04	11·80
Spelter, ordinary	13·69	15·74
Tin, standard	135·94	194·59
Pig-iron, Cleveland No. 3	2·92	3·03
Steel rails	8·37	8·37
Ferro-manganese	11·25	11·25
Gold, fine, per ounce	118·037 sh.	124·802 sh.
Silver, standard, per ounce	17·834 *d.*	18·148 *d.*
Ores—		
Chromite, 48-57 per cent., per ton	£4·698	£4·625
Manganese-ore, first grade, per unit	9·5 *d.*	9·5 *d.*
Wolfram, per unit	12·31 sh.	15·42 sh.

In Part 4 of Volume LXVI of these *Records* is a paper giving tables of production, imports, exports, and consumption of minerals and metals in India for 1913, 1917, 1920, and 1926 to 1931.

These data are given in considerable detail and similar data could not easily be obtained in full in time for incorporation in successive annual reviews of mineral production without causing undue delay. It is possible, however, to bring up to date Table V of that review showing the quantities of ores, metals and other mineral products available for consumption in India. These data for 1933 are summarised in Table 3 of this present Review.

TABLE 3.—*Consumption, 1933.*

Ores, minerals and metals.	Kinds and grades.	Unit.	Production.	Retained imports.	Exports of domestic production.	Ores, minerals and metals available for consumption. Columns 4+5—6.
1	2	3	4	5	6	7
Aluminium . .	Aluminium unwrought (ingots, blocks, etc.).	Cwts.	—	138	..	138
	Bauxite . . .	Tons	1,075	..	..	(*ca*) 1,000
Amber . . .	....	Lbs.	76	..	..	76
Antimony . .	Antimonial lead . .	Tons	1,485	..	(*a*)	..
Aquamarine . .	....	Carats	39,000	..	..	39,000
Arsenic . . .	Arsenic and its oxides .	Cwts.	(*b*)	2,020	..	2,020
Barytes . .	....	Tons	5,651	2,914	..	8,565
Beryl . . .	....	Tons	324	..	(*a*)	..
Bismuth . .	Mostly native . .	Lbs.	80	..	..	80
Borates . .	Borax (including boracic acid).	Cwts.	(*b*)	20,815	..	20,815
Brass . . .	....	Tons	6,143	(*c*) 22,097	271	27,969
Clays . . .	Clays other than China clay.	Tons	208,067	..	..	208,067
	China clay . . .	Tons	21,935	..	..	21,935
Chrome-ore . .	Chromite . . .	Tons	15,526	..	(*d*) 17,232	..
Coal, coke and bye-products.	Bituminous non-coking coal, bituminous coking coal, anthracite.	Tons	19,789,163	67,330	426,176	19,430,317
	Coal tar and pitch. .	Tons	43,616	8,445	..	52,061
	Sulphate of ammonia .	Tons	9,885	32,875	1,313	41,447
Copper . . .	Metal unwrought . .	Tons	4,800	630	..	5,430
Copper-matte .	....	Tons	12,550	..	(*e*) 11,887	..
Diamonds . .	....	Carats	2,342	(*f*)	..	2,342
Ferro-manganese .	....	Tons	7,725	..	..	7,725
Ferro-alloys . .	....	Tons	..	1,432	..	1,432
Felspar . . .	....	Tons	677	..	..	677

Fuller's earth	....	Tons	7,257	..	..	7,257
Garnet sand	....	Tons	(a) 295	..	..	..
Gold	....	Fine Ounces	336,108	140,106	(g) 6,248,095	..
Graphite	....	Tons	..	532	..	532
Gypsum	....	Tons	33,142	..	..	33,142
Ilmenite	....	Tons	43,384	..	(a)	..
Iron	Ore	Tons	1,228,625	..	..	1,228,625
	Pig	Tons	1,057,837	1,848	372,015	687,670
	Steel	Tons	505,429	72,744	29,183	548,990
	Manufactures of iron or steel other than those included under "Steel".	Tons	(h)	232,671	16,079	..
Jadeite	....	Cwts.	1,171	..	2,111	..
Lead	Ore	Tons	454,791	..	..	454,791
	Pig	Tons	70,560	134	65,045	5,649
Magnesite	....	Tons	15,206	..	(a)	..
Manganese-ore	....	Tons	218,307	..	376,354	..
Mica	....	Cwts.	41,075	376	57,717	..
Monazite	....	Tons	(h)	..	(a)	..
Nickel-speiss	....	Tons	3,350	..	(a)	..
Ochre	....	Tons	11,630	..	..	11,630
Petroleum	Crude	Gals.	306,009,022	..	..	306,009,022
	Petrol including benzene and dangerous spirit.	Gals.	68,818,733	2,379,708	66	71,198,375
	Kerosene	Gals.	139,354,915	57,778,363	..	197,133,278
	Fuel oil	Gals.	17,699,739	104,968,758	..	122,668,497
	Batching and lubricating oils.	Gals.	9,623,817	19,833,481	..	29,457,298
	Paraffin wax	Tons	46,795(i)	187	51,763	..

(a) Known to be exported, but export figures are not available.
(b) Known to be produced, but production figures are not available. (c) Including bronze and similar alloys.
(d) Includes 3,822 tons of chromite produced in British India but exported from Mormugao in Portuguese India.
(e) Presumably refers to Copper-matte.
(f) Quantity not known. Value of diamonds imported in 1933 amounted to Rs. 63,12,804.
(g) Total exports, largely imported in previous years.
(h) Not available. (i) One ton is assumed to be equivalent to 280 gallons.

TABLE 3.—*Consumption, 1933*—contd.

Ores, minerals and metals.	Kinds and grades.	Unit.	Production.	Retained imports.	Exports of domestic production.	Ores, minerals and metals available for consumption. Columns 4+5—6.
1	2	3	4	5	6	7
Phosphates	....	..	..	3,429	..	3,429
Potash, minerals and chemicals including saltpetre.	Saltpetre	Cwts.	(a) 198,567	..	189,567	9,000
	Potash, chemicals and manures.	Cwts.	..	109,716	..	168,832
Quicksilver	....	Lbs.	..	239,090	..	239,090
Refractory materials	....	Tons	(b) 19,284	..	(c)	..
Salt	....	Tons	(d) 1,404,255	366,818	14	1,771,059
Silver	....	Ounces	6,080,241	5,325,653	58,328,890	..
Steatite	....	Tons	17,048	..	..	17,048
Sulphur	....	Cwts.	..	404,232	..	404,232
Tin	Ore	Tons	4,960	..	2,945	2,015
	Metal (unwrought)	Cwts.	..	41,655	..	41,655
Tungsten	Ore	Tons	2,147	..	3,874	..
Zinc	Concentrates	Tons	61,432	..	64,050	..
	Metal (unwrought)	Tons	..	12,610	..	12,610
	Metal (wrought)	Tons	..	1,515	..	1,515
Zircon	....	Tons	603	..	(e)	..

(a) 189,567 cwts. exported *plus* 9,000 cwts. consumed in tea gardens in India.
(b) Includes 4,283 tons of kyanite.
(c) Known to be exported in part, but export figures are not available.
(d) Excludes production in Aden.
(e) Known to be exported, but export figures are not available.

II.—MINERALS OF GROUP I.

Antimony.

The production of antimonial lead obtained as a bye-product in the lead refinery at the Namtu smelter of the Burma Corporation Limited, increased from 642 tons valued at Rs. 88,140 (£6,627) in 1932 to 1,485 tons valued at Rs. 2,39,363 (£17,997) in 1933. This product contains approximately 74 per cent. of lead, 24 per cent. of antimony, and 4·5 ozs. of silver to the ton, and is exported for further treatment.

There has been no production of antimony-ore in the Amherst district, Burma, since 1930, when the output amounted to 3 tons valued at Rs. 60 (£4).

Chromite.

There was a further decrease in the production of chromite in India from 17,865 tons in 1932 to 15,526 tons in 1933. This decrease is the balance of a small revival in the output of Baluchistan, and a considerable decrease in the output of Mysore. The large increase recorded in the previous year in the output of Singhbhum was nearly maintained in the year under review. The total exports from India during the year were substantially below those of the previous year, but were nearly 2,000 tons in excess of the production, amounting to 17,232 tons, made up of 13,410 tons from British India and 3,822 tons from Mormugao in Portuguese India, as compared with 20,640 tons and 4,998 tons respectively in the previous year. The decrease in production was accompanied by a fall in the value per ton from Rs. 15·4 in 1932 to Rs. 14·4 in 1933.

Of recent years over 40 per cent. of the world's supply of chromite has been derived from Southern Rhodesia. But the great fall in demand from 1931 onwards has affected Rhodesia so seriously that in 1932 the Rhodesian production was less than that of India.

TABLE 4.—*Quantity and value of Chromite produced in India during the years 1932 and 1933.*

—	1932.			1933.		
	Quantity.	Value (£1=Rs. 13·3).		Quantity.	Value (£1=Rs. 13·3).	
	Tons.	Rs.	£	Tons.	Rs.	£
Baluchistan—						
Zhob . .	228	3,420	257	2,702	40,530	3,047
Bihar and Orissa—						
Singhbhum .	7,638	1,08,972	8,193	7,068	1,01,904	7,662
Mysore State—						
Hassan .	2,812	18,421	1,385	3,479	40,427	3,040
Mysore .	7,187	1,44,862	10,892	2,277	40,384	3,036
TOTAL .	17,865	*2,75,675*	*20,727*	15,526	*2,23,245*	*16,785*

Coal.

Although there was a continuance during 1933 of the decrease in production of coal from the peak production of 23,803,048 tons in 1930, yet the decrease was only 364,224 tons or about 1·8 per cent., as contrasted with decreases of 8·8 per cent. and 7·2 per cent. in 1931 and 1932 respectively. This decrease was due mainly to Bihar and Orissa and Bengal with smaller falls in Hyderabad, Baluchistan, Assam, and Rajputana, partially balanced by a very large increase in the production of the Central Provinces, with smaller increases in the Punjab and Central India. The substantial decrease in Bengal and Bihar and Orissa in 1933 is in continuation of the heavy decreases of 1931 and 1932. In 1932 this fall was shared by all the fields except Talcher, which showed a substantial increase of 111,274 tons. During 1933, however, five fields showed increases of which Talcher was responsible for 62,953 tons and Giridih for 52,681 tons, the increases for Jainti, the Rajmahal Hills and Rampur being trivial. The decrease was shared by the remaining four fields as follows:—Jharia, 536,334 tons; Raniganj, 153,304 tons; Karanpura, 65,690 tons, and Bokaro, 44,109 tons. In Central India there was, in contrast to the continuous decreases of the last 4 years, an increase in the output from Umaria of 6,085 tons; in addition, there was an increase of 6,195 tons from the Sohagpur field. In the Central Provinces there was another large increase amounting to 146,362 tons in the output from the Pench

Valley, whilst the output from Korea State, which showed an initial production of 3,517 tons in 1930, rising to 31,351 tons in 1931, 113,858 tons in 1932, amounted to 264,257 tons in 1933, representing the very large increase of 150,399 tons. In addition, Ballarpur showed an increase of 38,923 tons. In Hyderabad State, whilst the Singareni field was responsible for a decrease of some 74,000 tons, and Sasti for a decrease of over 11,000 tons, the Tandur coalfield showed an increase from the initial output of 126,471 tons from 1932 to 184,165 tons in 1933.

A feature of the last 10 years has been the very large expansion of the output from the Central Provinces from 679,081 tons in 1924 to 1,500,911 tons in 1933. This has undoubtedly accentuated the fall in output of Bihar and Orissa from 14,105,529 tons in 1924 to 11,257,984 tons in 1933.

In 1929 the statistical position at the end of the year showed a very great improvement in spite of the increase in the total output, stocks in the six provinces of Assam, Baluchistan, Bengal, Bihar and Orissa, the Central Provinces and the Punjab, for which such figures are available, showing a total reduction of 781,477 tons. In 1930 the smaller increase in production was not accompanied by another improvement in the statistical position, but by a slight worsening, namely an increase of stock amounting to 141,766 tons. In 1931, in spite of a large fall in production of over 2,000,000 tons, the position deteriorated still further with an increase of stocks of 428,334 tons, and in 1932 this deterioration continued, so that in spite of a decreased output of over 1½ million tons stocks increased by 250,629 tons. During 1933 the position showed no substantial change, but the slight reduction of stocks may be symptomatic of a tendency towards a better adjustment of production to demand. The data are given in the following table:—

Year.	Opening stock.	Closing stock.	Reduction during year.
	Tons.	Tons.	Tons.
1927	2,161,806	1,721,288	*440,518*
1928	1,721,288	1,625,717	*95,571*
1929	1,625,717	844,240	*781,477*
1930	844,240	986,006	(*a*) 141,766
1931	986,006	1,414,340	(*a*) 428,334
1932	1,414,340	1,664,969	(*a*) 250,629
1933	1,664,969	1,646,248	*18,721*

(*a*) Increase of stocks.

The decreased output of 1·8 per cent. in 1933 was accompanied by a decrease of 10.1 per cent. in the total value of the coal produced in India from Rs. 6,80,96,604 (£5,120,045) in 1932 to Rs. 6,11,86,083 (£4,600,457) in 1933.

There was a further decrease of Re. 0-4-7 in the pit's mouth value per ton of coal for India as a whole, namely from Rs. 3-6-1 to Rs. 3-1-6, a further very serious fall at this low level of prices. With one exception a fall was recorded in every province. In the two great coal provinces, Bihar and Orissa and Bengal, the value fell by Re. 0-3-10 and Re. 0-6-3 respectively. In other provinces, the price fell in Assam by Re. 1-8-5; in Baluchistan by Re. 0-15-8; in the Punjab by Re. 0-8-5; in Hyderabad by Re. 0-8-1; in Central India by Re. 0-4-5, and in the Central Provinces by Re. 0-1-0. On the other hand the price rose in Rajputana by Re. 0-5-8.

TABLE 5.—*Provincial production of Coal during the years 1932 and 1933.*

Province.	1932.	1933.	Increase.	Decrease.
	Tons	Tons	Tons	Tons
Assam	210,035	194,154	..	15,881
Baluchistan	18,928	11,462	..	7,466
Bengal	5,782,603	5,691,189	..	91,414
Bihar and Orissa	11,847,216	11,257,984	..	589,232
Central India	240,488	252,768	12,280	..
Central Provinces	1,163,096	1,500,911	337,815	..
Hyderabad	781,121	753,402	..	27,719
Punjab	72,857	94,099	21,242	..
Rajputana	37,043	33,194	..	3,849
TOTAL	20,153,387	19,789,163	371,337	735,561

TABLE 6.—*Value of Coal produced in India during the years 1932 and 1933.*

	1932.			1933.		
	Value (£1 = Rs. 13·3).		Value per ton.	Value (£1 = Rs. 13·3).		Value per ton.
	Rs.	£	Rs. A. P.	Rs.	£	Rs. A. P.
Assam	22,70,039	170,680	10 12 11	18,02,042	135,492	9 4 6
Baluchistan	1,49,385	11,232	7 14 3	79,239	5,958	6 14 7
Bengal	1,88,07,330	1,414,085	3 4 0	1,62,67,325	1,223,107	2 13 9
Bihar and Orissa	3,78,23,891	2,843,901	3 3 1	3,32,42,520	2,499,437	2 15 3
Central India	10,06,944	75,710	4 3 0	9,88,182	74,299	3 14 7
Central Provinces	44,41,896	333,977	3 13 1	56,40,432	424,093	3 12 1
Hyderabad (*a*)	30,63,495	230,338	3 14 9	25,74,111	193,542	3 6 8
Punjab	3,83,155	28,809	5 4 2	4,45,629	33,506	4 11 9
Rajputana	1,50,469	11,313	4 1 0	1,46,603	11,023	4 6 8
TOTAL	**6,80,96,604**	**5,120,045**	..	**6,11,86,083**	**4,600,457**	..
AVERAGE	..	..	*3 6 1*	..	..	*3 1 6*

(*a*) Estimated.

TABLE 7.—*Origin of Indian Coal raised during the years 1932 and 1933.*

—	Average of last five years.	1932.	1933.
	Tons	Tons	Tons
Gondwana coalfields	21,928,734	19,814,524	19,456,254
Tertiary coalfields	398,162	338,863	332,909
TOTAL	**22,326,896**	**20,153,387**	**19,789,163**

TABLE 8.—*Output of Gondwana Coalfields during the years 1932 and 1933.*

—	1932.		1933.	
	Tons.	Per cent. of Indian total.	Tons.	Per cent. of Indian total.
Bengal, Bihar and Orissa—				
Bokaro	1,348,973	6·69	1,304,864	6·60
Giridih	583,243	2·90	635,924	3·21
Jainti	43,163	0·21	43,530	0·22
Jharia	8,551,283	42·43	8,014,949	40·50
Karanpura	409,566	2·03	343,876	1·74
Rajmahal Hills	1,500	0·01	1,752	0·01
Rampur(Raigarh-Hingir)	19,498	0·10	22,036	0·11
Raniganj	6,419,007	31·85	6,265,703	31·66
Talcher	253,586	1·26	316,539	1·60
Central India—				
Sohagpur	166,195	0·82	172,390	0·87
Umaria	74,293	0·37	80,378	0·41
Central Provinces—				
Ballarpur	217,421	1·08	256,344	1·29
Korea	113,858	0·56	264,257	1·34
Pench Valley	831,817	4·13	978,179	4·94
Raigarh State	..	..	2,131	0·01
Hyderabad—				
Sasti	61,184	0·30	49,794	0·25
Singareni	593,466	2·95	519,443	2·63
Tandur	126,471	0·63	184,165	0·93
TOTAL	19,814,524	*98·32*	19,456,254	*98·32*

TABLE 9.—*Output of Tertiary Coalfields during the years 1932 and 1933.*

—	1932.		1933.	
	Tons.	Per cent. of Indian total.	Tons.	Per cent. of Indian total.
Assam—				
Khasi and Jaintia Hills	1,233		2,118	
Makum	170,399	1·04	164,412	0·98
Naga Hills	38,403		27,624	
Baluchistan—				
Khost	5,297	0·10	4,376	0·06
Sor Range, Mach, Kalat	13,631		7,086	
Punjab—				
Jhelum	32,527		41,062	
Mianwali	30,792	0·36	45,581	0·47
Shahpur	9,538		7,456	
Rajputana—				
Bikaner	37,043	0·18	33,194	0·17
TOTAL	338,863	*1·68*	332,989	*1·68*

The development of an iron and steel industry in India on modern lines has led to the erection of several plants for the manufacture of hard coke of metallurgical quality, and it has therefore become a matter of general interest to know the proportion of the total annual output of coal in India that is utilised in the manufacture of hard coke.

The figures for 1932 and 1933 are shown in Table 10.

TABLE 10.—*Quantity of Hard Coke produced in India in the years 1932 and 1933.*

——	1932.	1933.
	Tons	Tons
Coal used	1,635,972	1,655,197
Hard coke manufactured	1,214,526	1,227,190
Percentage recovery	*74·24*	*74·14*
Source of coal used—		
Jharia field	1,585,733	1,517,483
Giridih field	32,724	27,245
Bokaro field	4,637	..
Raniganj field	12,878	110,469
TOTAL	1,635,972	1,655,197
Coal used for coking by—		
Three iron and steel companies	1,322,969	1,343,151
Others	313,003	312,046

In reversal of 1932, the export statistics for coal during 1933 show a decrease amounting to about 93,300 tons (*see* Table 11). Exports to Ceylon showed a partial recovery, increasing from 190,237 tons in 1932 to 229,040 tons in 1933, Ceylon thereby resuming her position as the leading importer of Indian coal. Exports to all other destinations decreased, the decreases being some 79,000 tons to Hongkong, 23,000 tons to the Philippine Islands and Guam, 5,000 tons to the Straits Settlements, and 3,000 tons to the United Kingdom. The export of coke decreased by 842 tons.

TABLE 11.—*Exports to Foreign Ports of Indian Coal and Coke during the years 1932 and 1933.*

—	1932.			1933.		
	Quantity.	Value (£1 = Rs. 13·3).		Quantity.	Value (£1 = Rs. 13·3).	
	Tons	Rs.	£	Tons	Rs.	£
To—						
Ceylon . . .	190,237	22,63,725	170,205	229,040	26,73,284	200,999
Hongkong . . .	218,638	17,34,610	130,422	139,726	9,10,935	68,491
Philippines . .	29,043	2,53,326	19,047	6,242	39,012	2,933
Straits Settlements .	13,058	1,33,352	10,027	8,349	69,539	5,229
United Kingdom .	32,699	3,72,953	28,041	29,802	3,13,232	23,551
Other countries . .	33,854	3,79,943	28,567	11,815	83,680	6,292
TOTAL .	517,529	51,37,909	386,309	425,064	40,89,682	307,495
Coke	1,954	38,955	2,929	1,112	20,789	1,563
Total of Coal and Coke	**519,483**	*51,76,864*	*389,238*	**426,176**	*41,10,471*	*309,058*

The following table gives the amounts of different grades of coal exported during 1932 and 1933 under the Indian Coal Grading Board's scheme (including sea-borne coal for railways in Southern India, for which no grade shipment certificates were issued by the Coal Grading Board) and shows a decrease of 319,904 tons in the present year, the difference between the total amounts so exported (1,889,181 tons in 1933) and the total exports of Indian coal to foreign ports given in Table 11 (426,176 tons in 1933) being the amount of coal exported to Indian ports.

TABLE 12.—*Exports of Coal under Grading Board Certificates during the years 1932 and 1933.*

—	1932.	1933.
	Tons	Tons
Selected grade	1,987,808	1,706,421
Grade I	211,534	175,417
Grade II	6,120	596
Mixed grade	3,623	6,747
TOTAL .	**2,209,085**	**1,889,181**

In reversal of the trend of the past few years imports of coal and coke showed during 1933 an increase, namely from 47,544 tons in 1932 to 67,330 in 1933; 21,121 tons of the latter consisted of coke (*see* Table 13). This rise is due mainly to an increase of some 17,000 tons from South Africa, and of 7,000 tons of coke, offset by a decrease of 9,000 tons of coal from the United Kingdom. The total imports are now about a seventh of those of the pre-war quinquennium and Table 14 comparing pre-war imports and exports with the figures from 1926 to 1933, shows that the depression in the Indian coal industry, which was accentuated in 1933, cannot be ascribed to the competitive effect of foreign imported coal. The average surplus of exports over imports during the years 1926 to 1933 was, in fact, greater than the surplus during the pre-war quinquennium.

The true cause of the depression in the Indian coal industry is over-development of coalfields with reference to India's requirements. Every new coalfield that is opened up at present merely serves to accentuate the depression.

TABLE 13.—*Imports of Coal and Coke during the years 1932 and 1933.*

—	1932.			1933.		
	Quantity.	Value (£1 = Rs. 13·3).		Quantity.	Value (£1 = Rs. 13·3).	
	Tons	Rs.	£	Tons	Rs.	£.
From—						
Australia . . .	4,070	93,760	7,050	4,248	82,622	6,212
United Kingdom .	18,505	4,05,487	30,488	9,924	2,18,974	16,464
Union of South Africa .	8,620	1,20,350	9,049	26,044	3,92,990	29,548
Other countries . .	2,437	40,402	3,044	5,993	83,943	6,312
TOTAL .	33,632	6,60,080	49,631	46,209	7,78,520	58,536
Coke	13,012	3,46,275	26,036	21,121	4,74,468	35,674
TOTAL OF COAL AND COKE	47,544	*10,06,364*	*75,667*	67,330	*12,52,997*	*94,210*

TABLE 14.—*Excess of exports over imports of Coal.*

——	Exports.	Imports.	Excess of exports over imports.
	Tons	Tons	Tons
Average for 1909-13	814,475	466,162	348,313
1926	617,563	193,908	423,655
1927	576,167	243,603	332,564
1928	626,343	210,186	416,157
1929	726,610	218,560	508,050
1930	461,188	217,029	244,159
1931	441,249	88,035	353,214
1932	519,483	47,544	471,939
1933	426,176	67,330	358,846

The average number of persons employed in the coalfields during the year showed a somewhat smaller decrease (1·4 per cent.) than the decrease in production (1·8 per cent.). The average output per person employed, therefore, showed a trivial decrease to 121·3 tons in contrast with the advances up to 1930, which have been 110·5 tons for 1925, rising to 113·1 tons for 1926, 122·3 tons for 1927, 125·5 tons for 1928, 130·4 tons for 1929, and 129·1 tons for 1930, with decreases to 125·4 tons in 1931 and to 121·7 tons in 1932. Except for the last six years, however, the figure for the year under review is still higher than those previously recorded; these higher figures are due, partly to an increased use of mechanical coal-cutters, and partly to concentration of work. During the past few years a large number of collieries have been shut down and the labour absorbed in the remainder; this concentration permits of a proportional reduction of the supervising staff, resulting in a larger tonnage per head. There was a decrease in the number of deaths by accident from 164 in 1932 to 132; these figures are much better than the annual average for the quinquennium 1919-1923, which was 274, and also below the annual average for the quinquennium 1924-1928, which was 218. The death rate was 0·81 per thousand persons employed in 1933, markedly less than the figure for the previous year (1·0); the average figure for the period 1919-1923 was 1·36, and for the period 1924-1928 was 1·16.

TABLE 15.—*Average number of persons employed daily in the Indian Coalfields during the years 1932 and 1933.*

——	1932.	1933.	Output per persons employed in tons.	Number of deaths by accident.	Death rate per 1,000 persons employed.
Assam	2,275	1,978	98·2	6	3·0
Baluchistan . . .	264	275	41·6	..	..
Bengal	43,423	43,651	130·4	27	0·6
Bihar and Orissa . .	95,082	88,571	127·1	72	0·8
Central India . . .	2,108	2,133	118·5	2	0·9
Central Provinces . .	10,221	13,890	108·0	17	1·2
Hyderabad . . .	10,753	11,046	68·2	6	0·5
Punjab	1,315	1,516	62·1	2	1·3
Rajputana . . .	126	113	293·7	..	..
TOTAL .	**165,567**	**163,173**	..	**132**	..
AVERAGE .	..	..	*121·3*	..	*0·81*

Cobalt (*see* Nickel).

Copper.

The progress of work at the Mosaboni Mine of the Indian Copper Corporation, Ltd., in the Singhbhum district, and on the milling and smelting plant at Maubhandar, near Ghatsila, Bengal Nagpur Railway, has been noticed in previous reviews. Operations commenced on a revenue basis on January 1st, 1929. During that year the ore produced amounted to 76,831 long tons valued at Rs. 14,58,746 (£108,862). Of this 75,174 short tons were treated in the mill and smelter, with the production of 1,635 long tons of refined copper ingots and slabs. The copper was sold entirely in India at an average price of Rs. 1,200 per long ton. In 1930 the output increased to 123,749 long tons of copper-ore valued at Rs. 24,35,571 (£180,413). Of this 134,162 short tons were treated in the mill and smelter and 1,625 short tons sent direct to the smelter with the production of 2,974 long tons of refined copper, of which 2,157 tons were sold in the Indian market and 540 tons were consumed in the new rolling mill, which was completed in July 1930, with the production of 712 tons of yellow metal (brass) sheet, which found a ready market in Calcutta.

Since then in spite of falling prices the production of both mine and smelter has continued to expand. In addition during 1933 there was an initial production of ore from Dhobani where a lode parallel to that at Mosaboni is being opened up. During 1933 the mine output increased to 201,515 long tons of copper-ore from Mosaboni and 207 long tons from Dhobani, making a total of 201,722 long tons, valued at Rs. 22,12,966 (£166,388), against 175,010 long tons of copper ore in 1932 valued at Rs. 25,09,080 (£188,652). 203,736 short tons of ore were treated in the mill and the production of refined copper amounted to 4,800 long tons against 4,443 tons in the previous year. 3,774 tons were consumed in the rolling mill and 1,317 tons were sold in the Indian market at an average price of Rs. 599 per ton. Operations in the rolling mill resulted in the production of 6,143 long tons of yellow metal, the whole of which was sold in India at an average price of Rs. 631 per ton.

The total ore reserves at the close of the year 1933 amounted to 686,402 short tons with an average assay value of 3·06 per cent. of copper.

In reversal of the trend of the past two years there was an increase in the production of copper-matte at the Namtu smelting plant of the Burma Corporation, Limited, from 9,729 tons valued at Rs. 19,81,499 (£148,985) in 1932 to 12,550 tons valued at Rs. 30,03,983 (£225,863), and averaging 43·55 per cent. of copper, 24·30 per cent. of lead, and 86·76 ozs. of silver to the ton.

In 1932 365 tons of copper-ore valued at Rs. 6,900 (£519) were produced in the Nellore district, Madras. There was no recorded production in 1933.

Diamonds.

The production of diamonds in Central India rose from 1,254·1 carats valued at Rs. 72,189 (£5,428) in 1932, to 2,342 carats valued at Rs. 63,695 (£4,789) in 1933. Of this latter production 2,271 carats were produced in Panna State and the remainder in Charkhari, Ajaigarh, and Bijawar.

Gold.

In 1931 the gradual secular decline in the total Indian gold production was temporarily arrested with an output of 330,488·8 ozs. valued at Rs. 2,08,01,943 (£1,540,885), followed by a trivial

fall again in 1932, when the output was 329,681·7 ozs. valued at Rs. 2,53,51,438 (£1,906,123). In 1933 there was an increase to 336,108·3 ozs. valued at Rs. 2,76,40,071 (£2,078,201). This is a result of the stimulus of the high price of gold, the value of the 1933 output being the highest in terms of sterling since 1920. It is interesting to note that the output of 1921 which was valued at £2,050,575 a figure very close to that of the 1933 production, was 432,722·6 ozs.

There was again a small production from Singhbhum and also a small output from Manbhum; and as in the previous year small outputs from Burma, the Punjab and the United Provinces. But these figures are, of course, quite insignificant compared with the output of Kolar which makes up 99·9 per cent. of the Indian total. The considerable increase in the value of the production in 1932 was due to that being the first full year since Britain and India abandoned the gold standard in September, 1931, with consequent appreciation in price of gold, against sterling or rupees. As a result of this appreciation in the price of gold, 9,766,122 ozs. of gold reckoned in terms of fine gold were exported during 1932. The value was Rs. 75,87,52,203 (£57,049,038). In 1933 the exports were 6,248,095 ozs. valued at Rs. 51,25,48,810 (£38,537,505).

Of the five mines that were producing gold on the Kolar goldfield, the Balaghat Gold Mine was, owing to unfavourable development in depth, sold on the 1st May, 1932, to the Nundydroog Mines, Ltd., the latter company undertaking to mine and treat the ore reserves remaining in the Balaghat Mine. The Champion Reef and the Ooregum Mines, the two deepest on the field, reached vertical depths of 7,410 feet and 7,334 feet respectively below field datum on the 31st December, 1933. The development in depth has disclosed the continuity of the reef, and a number of shoots of payable ore have been opened up. At these depths the dip of the reef is almost vertical. The ore is not refractory and yields its gold to blanket concentration and cyaniding; 'all-sliming' practice is becoming general. The concentrates are pan or plate-amalgamated. The rock temperature at the 78th level Champion Reef Mine was 129·8° F. Owing to the great depths of these mines and the consequent high temperatures, the maintenance of adequate ventilation at the working places continues to be an extremely difficult problem. It has been partly solved by sinking deep smooth-lined vertical shafts, circular or eliptical, and by an extensive use of large electrically-driven fans in the course of the main air currents. The sub-

sidiary shafts and winzes in the lower levels are all brick or concrete-lined and as such assist the free movement of air by reducing friction to a minimum. In spite of the more rigid forms of support, such as packs of masonry and concrete and sand filling, rockbursts continue to occur causing considerable damage to person and property.

The average number of persons employed on the Kolar Gold Field during 1933 was 20,263.

TABLE 16.—*Quantity and value of Gold* produced in India during the years 1932 and 1933.*

—	1932.			1933.			Labour in 1933.
	Quantity.	Value (£1 = Rs. 13·3).		Quantity.	Value (£1 = Rs. 13·3).		
	Ozs.	Rs.	£.	Ozs.	Rs.	£.	
Bihar and Orissa—							
Manbhum	..	..	..	42·0	2,988	225	10
Singhbhum	50·0	3,650	274	225·0	16,750	1,259	58
Burma—							
Katha	18·2	950	72	31·0	1,665	125	2
Upper Chindwin.	28·4	2,649	199	21·0	1,960	147	..
Mysore	329,574·9	2,53,43,443	1,905,522	335,773·9	2,76,15,478	2,076,352	20,263
Punjab	6·6	480	36	10·3	825	62	41
United Provinces	3·6	266	20	5·1	405	31	27
TOTAL	329,681·7	*2,53,51,438*	*1,906,123*	336,108·3	*2,76,40,071*	*2,078,201*	*20,401*

* Fine ounces in the case of Mysore.

Ilmenite.

There was a large decrease in the production of ilmenite in Travancore State from 50,052·5 tons valued at £58,134 in 1932, to 43,384 tons valued at £ 43,384 in 1933. This mineral occurs

in the monazite sands and, up to a few years ago, was looked upon as a bye-product of the monazite industry. The monazite sands have been worked continuously since 1911, but it was not until 1922 that the export of ilmenite commenced, since when, except for the decrease in 1933, the production of the mineral has expanded almost continuously, so that in both quantity and value the production of ilmenite is now much more important than that of the associated minerals monazite and zircon. This steady increase in the output of ilmenite is due to the demand for its contents of titanium dioxide in the manufacture of titanium paints.

Iron.

For some years up to and including 1929 the production of iron-ore in India had been steadily increasing; India is now, in fact, the second largest producer in the British Empire, and yields place only to the United Kingdom. Her output is of course still completely dwarfed by the production in the United States (over 31 million tons in 1931 and nearly 10 million tons in 1932) and France (38 and 27 million tons in 1931 and 1932 respectively); but her reserves of ore are not much less than three-quarters of the estimated total in the United States, and there is every hope that India will eventually take a much more important place among the world's producers of iron-ore. In 1930, however, the prevailing depression was reflected in a decrease in the Indian output over the previous year of 23·8 per cent. amounting to 578,930 tons, followed by a further fall of 224,742 tons (12·1 per cent.) in 1931. In 1932 in spite of the continuance of the depression there was a partial recovery in the production of iron-ore in India of 135,618 tons (8·3 per cent.). In 1933, however, there was a further decrease of 531,876 tons (30·2 per cent.); but, as will be seen later, there were increases in the output of pig-iron and steel. The figures shown against the Keonjhar and Mayurbhanj States in Table 17 represent the production by the United Steel Corporation of Asia, Ltd., and the Tata Iron and Steel Co., Ltd., respectively. Of the total production of 616,946 tons shown against Singhbhum, 469,114 tons were produced by the Tata Iron and Steel Co., Ltd., from their Noamundi mine, and 147,832 tons by the Indian Iron and Steel Co., Ltd., from their mines at Gua. The output of iron-ore in Burma is by the Burma Corporation, Limited, and is used as a flux in lead smelting.

TABLE 17.—*Quantity and value of Iron-ore produced in India during the years 1932 and 1933.*

—	1932.			1933.		
	Quantity.	Value (£1 = Rs. 13·3).		Quantity.	Value (£1 = Rs. 13·3).	
	Tons.	Rs.	£	Tons.	Rs.	£
Bihar and Orissa—						
Keonjhar State	186,173	1,86,173	13,998	195,944	1,95,943	14,733
Mayurbhanj State	891,193	21,33,961	160,448	341,502	6,32,129	47,529
Sambalpur	7	50	4	4	30	2
Singhbhum	666,874	15,51,217	116,633	616,946	13,83,773	104,043
Burma—						
Northern Shan States	6,560	(a) 26,240	1,973	36,293	(a)1,45,172	10,915
Central Provinces	803	2,409	181	777	2,331	175
Madras—						
East Godavari	4,496	4,456	335	2,118	1,291	97
Mysore State	4,395	15,263	1,148	35,041	1,37,245	10,319
TOTAL	1,760,501	*39,19,769*	*294,720*	1,228.625	*24,97,914*	*187,813*

(a) Estimated.

In contrast with the preceding year there was a rise in the total output of iron and steel by the Tata Iron and Steel Co. at Jamshedpur. The production of pig-iron rose from 699,931 tons in 1932 to 793,953 tons in 1933, with increases in the production of steel (including steel rails) from 430,333 tons in 1932 to 505,429 tons in 1933, and of ferro-manganese from 366 tons in 1932 to 7,725 tons in 1933. As in 1932, there was no production of pig-iron by the Bengal Iron Co.; their output of products made from pig-iron in 1933 amounted to 12,511 tons of sleepers and chairs, and 23,263 tons of pipes and other castings, against 3,371 tons and 17,266 tons, respectively, in 1932. The Indian Iron and Steel Co. increased their production of pig-iron from 198,700 tons in 1932 to 249,079 tons in 1933. The output of pig-iron by the Mysore Iron Works rose slightly from 14,683 tons in 1932 to 14,805 tons in 1933. The total production of pig-iron in India rose from 913,314 tons in 1932 to 1,057,837 tons in 1933, and is shown in Table 18.

TABLE 18.—*Production of Pig-iron in India during the years 1932 and 1933.*

——	1932.	1933.
	Tons.	Tons.
The Tata Iron and Steel Company, Limited . .	699,931	793,953
The Indian Iron and Steel Company, Limited . .	198,700	249,079
The Mysore Iron Works	14,683	14,805
TOTAL .	**913,314**	**1,057,837**

The total number of indigenous furnaces that were at work in the Central Provinces during the year 1932 for the purpose of smelting iron-ore was 114 against 118 in the previous year; 52 furnaces were operating in the Bilaspur district, 54 in Mandla, 2 in Raipur, 1 in Saugor, 5 in Drug, and none in Jubbulpore.

The increase in the production of pig-iron in India recorded above was accompanied by a rise in the quantity exported from 248,390 tons in 1932 to 372,015 tons in 1933. Table 19 shows that Japan is the principal consumer of Indian pig-iron; the proportion taken rose from 41·5 per cent. in 1932 to 48·3 in 1933, whilst the actual amount rose by 76 per cent. There was also a large increase in exports to the United States of America of about 166 per cent. (44,973 tons) and an increase of 7,500 tons to China, with small decreases to the United Kingdom and Hongkong. The export value per ton of pig-iron fell from Rs. 34·8 (£2·62) in 1932 to Rs. 24·5 (£1·84) in 1933.

The Steel Industry (Protection) Act, 1924 (Act No. XIV of 1924), authorised, to companies employing Indians, bounties upon rails and fishplates wholly manufactured in British India from material wholly or mainly produced from Indian iron-ore and complying with specifications approved by the Railway Board, and upon iron or steel railway wagons, a substantial portion of the component parts of which had been manufactured in British India. This Act was repealed by the Act No. III of 1927 and the payment of bounties consequently ceased on the 31st March, 1927; the industry is, however, protected to a certain extent by varying tariffs on different classes of imported steel. An Act is now before the Legislative Assembly proposing considerable modification of the tariffs.

quantities and values reported since 1901, when the output was 120,891 tons valued at £122,831. In 1905 the output was 247,427 tons valued at £223,432, since when the smallest production was 450,416 tons in 1915 valued at £929,546; whilst the smallest value was in 1909 when a production of 644,660 tons was valued at £603,908. The full magnitude of this catastrophe to the Indian manganese industry is perhaps best realised from the fact that whilst the quantity of the production in 1933 was a little over one-fifth of that of the peak year of 1927, the value was less than one twenty-second part of the value of the 1927 production. In fact in none of the major Indian mineral industries have the effects of the slump been so seriously felt as in the manganese industry.

The slight increase in 1933 is due to increases in Sandur State (22,237 tons), Keonjhar State (15,499 tons), Vizagapatam (8,649 tons), and Singhbhum (5,181 tons), with small outputs from Bonai State and Kurnool, largely balanced by decreases in the Central Provinces. In the Central Provinces the production fell from 302,344 tons in 1931 to 77,186 tons in 1932, and 28,789 tons in 1933, which is less than the output of 1900, the year in which the manganese industry commenced in the Central Provinces, when the output was 35,356 tons. During 1932 and 1933 the majority of mines in the Central Provinces were closed including several mines that had never been closed since the commencement of work in 1900 and 1901. There was a total cessation of production in the Nagpur district and almost total cessation in Bhandara.

The distribution of increases and decreases in production in 1933 illustrates vividly the vital importance of lower railway freights on manganese-ore from the Central Provinces with its long lead to the ports; for although this tract produces the highest grade of ore the increases in output during 1933 were from the mines nearer the sea in spite of the fact that the majority of them produce second-grade ores.

In 1924, first-grade ore, c.i.f. United Kingdom ports, fetched an average price of 22·9*d.* per unit, in 1925 this price fell to 21·5*d.*, in 1926 to 18·4*d.*, in 1927 to 18·1*d.*, in 1928 to 17·0*d.*, with a heavy fall in 1929 to an average price of 14·0*d.* per unit. In 1930 the price fell to 13·1*d.* per unit, that is to the post-war lower governing price of manganese[1] for 1928, with an index figure of cost of supplies

[1] See *Rec. Geol. Surv., Ind.*, Vol. LXIV, p. 192, (1930).

and services of 1·45, in 1931 to 11·8*d*., and in 1932 to 9·5*d*. per unit, which was also the price during 1933.

This continued fall in the price of manganese-ore from 1924 to 1932 is to be correlated with the fact that from 1924 to 1927 the rate of increase of the world's production of manganese-ore was much greater than the rate of increase in the world's production of pig-iron and steel. And although there was a fall in the world's output of manganese-ore in 1928, there was a very large increase in 1929, greater than was justified by the increased production of iron and steel in that year, and it is evident that the world's available supplies of manganese-ore are now much in excess of requirements. Russia, by non-economic methods of exploitation and finance, is able to place large quantities of ore on the market at a price well below both the critical figure of 13·1*d*. referred to above and also below any revised figure allowing for the fall in index figures. The index figure for 1932 was 0·91 for which the corresponding lower governing price of manganese would be 7·8*d*. had labour charges and railway freights fallen accordingly. During 1932 the price of Russian ore fell from 9 to 9½*d*. c.i.f. at the beginning of the year to 8 to 9*d*. c.i.f. per unit at the end of the year, a price which persisted during 1933, and one with which India cannot compete without a return to pre-war railway freights and pre-war labour charges. The Indian trade has accordingly suffered disastrously. The large deposits of high-grade manganese-ore discovered near Postmasburg in South Africa are also being developed, and it may be anticipated that eventually South Africa will secure a substantial portion of the world's market. Production from this field was suspended during 1932, but was resumed in May, 1933. It is not surprising, therefore, that in spite of the apparent prosperity of the Indian manganese industry in 1929 and 1930 as judged from figures of production and export, yet by 1930 the industry as a whole had arrived at a stage of relative depression, causing many operators to cease work. Added to increased available supplies there has been in 1931 and 1932 the disastrous decline in the activities of the iron and steel industry of the world, illustrated by a decline from the peak figure of 122 million tons of steel in 1929 to about 68 million tons in 1931 and only 50 million tons in 1932. In 1933 there was a partial revival and the output of steel was some 69 million tons[1], and in early 1934 this has produced a slight hardening in the price of manganese-ore.

[1] *Mining Journal*, 10th February, 1934, p. 90.

The present chief sources of production of manganese-ore are India, Russia, the Gold Coast, South Africa, and Brazil, whilst substantial supplies of ore are forthcoming from Egypt and Czechoslovakia.

There is a steady consumption of manganese-ore at the works of the three principal Indian iron and steel companies, not only for use in the steel furnaces of the Tata Iron and Steel Company, and for the manufacture of ferro-manganese, but also for addition to the blast furnace charge in the manufacture of pig-iron. The consumption of manganese-ore by the Indian iron and steel industry in the year under review amounted to 39,395 tons, against 19,647 tons in 1932.

TABLE 21.—*Quantity and value of Manganese-ore produced in India during the years 1932 and 1933.*

—	1932.		1933.	
	Quantity.	Value f.o.b. at Indian ports.	Quantity.	Value f.o.b. at Indian ports.
	Tons.	£	Tons.	£
Bihar and Orissa—				
Bonai State	..	..	3,115	1,771
Keonjhar State	44,908	23,296	60,407	34,357
Singhbhum	2,272	2,300	7,453	7,919
Bombay—				
North Kanara	612	620	..	..
Central Provinces—				
Balaghat	36,762	40,132	20,501	23,405
Bhandara	10,918	11,919	60	69
Chhindwara	10,041	10,961	8,228	9,394
Nagpur	19,465	21,249	..	..
Madras—				
Kurnool	..	..	300	124
Sandur State	79,023	26,176	101,260	38,605
Vizagapatam	8,049	3,169	16,698	7,409
Mysore—				
Chitaldrug	219	79	5	2
Shimoga	335	121	280	116
TOTAL	**212,604**	***140,022***	**218,307**	***123,171***

In spite of the almost static depressed condition of the producing side of the industry during 1933, exports, including the quantities exported from Mormugao in Portuguese India, increased somewhat from the nadir of 301,252 tons in 1932 to 376,354 tons in 1933. The large increase in the exports from Vizagapatam is due to the opening of the new port. Table 23 shows the distribution of manganese-ore exported from British Indian ports (excluding Mormugao) during 1932 and 1933, from which it will be seen that the United Kingdom with an increase of some 40,000 tons became again the chief importer of Indian manganese-ore. The second place as importer was held by France with a decrease of some 15,000 tons, with Japan a close third with an increase of some 44,000 tons; Belgium again showed a decrease, amounting to some 7,000 tons. In 1932 the exports to the United States of America, one of India's principal markets for manganese-ore, had ceased completely. In 1933 there was a trivial export to this destination. The feature of the year was the large increase in the exports to Japan.

TABLE 22.—*Exports of Manganese-ore during 1932 and 1933 according to ports of Shipment.*

—	1932.	1933.
	Tons.	Tons.
Bombay	58,145	51,747
Calcutta	131,399	146,121
Vizagapatam	3,200	61,940
Mormugao (Portuguese India)	108,508	116,546
TOTAL	301,252	376,354

TABLE 23.—*Export of Manganese-ore from British Indian ports during the years 1932 and 1933.*

—	1932.			1933.		
	Quantity.	Value (£1 = Rs. 13·3).		Quantity.	Value (£1 = Rs. 13·3).	
	Tons.	Rs.	£	Tons.	Rs.	£
To—						
United Kingdom . .	54,397	15,45,175	116,179	95,292	20,54,516	154,475
Germany	1,056	19,874	1,494	2,785	58,334	4,386
Netherlands . . .	2,000	50,000	3,759	2,060	36,790	2,766
Belgium	26,402	7,60,645	57,368	19,422	4,26.620	32,077
France	82,521	19,66,799	147,880	67,094	12,08,010	90,828
Japan	21,868	4,56,873	34,351	65,904	12,15,755	91,410
United States of America .	..	..	..	11	585	44
Other countries . .	4,500	1,17,750	8,853	7,150	1,02,295	7,691
TOTAL .	192,744	*49,26,116*	*370,384*	259,808	*51,02,905*	*383,677*

Mica.

There was a marked rise in the declared production of mica from 32,713 cwts. valued at Rs. 14,35,401 (£107,925) in 1932 to 41,075 cwts. valued at Rs. 16,82,045 (£126,470) in 1933. As has been frequently pointed out, the output figures are incomplete, and a more accurate idea of the size of the industry is to be obtained from the export figures. In the years 1926 and 1927 the export figure was approximately double the reported production figure, whilst in the years 1928 and 1929 the quantity exported was more than double the reported production. In 1930 the recorded exports were, however, only some 57 per cent. in excess of the reported production, in 1931 36 per cent., in 1932 43 per cent., and in 1933 some 45 per cent., in excess. This may mean that the Act referred to in the third paragraph is now beginning to produce a definite effect. This will be conclusively proved only by statistics over a period of years.

The United States of America and the United Kingdom, which are the principal importers of Indian mica, absorbed respectively 24·0 per cent. and 47·6 per cent. during 1932, and 34·3 per cent. and 40·8 per cent. during 1933. Germany took 10·6 per cent.

and 10·7 per cent. respectively, of the total quantities exported during the years 1932 and 1933. The average value of the exported mica decreased slightly from Rs. 71·2 (£5·4) per cwt. in 1932 to Rs. 70·7 (£5·3) per cwt. in 1933. The exports rose from 47,021 cwts. valued at Rs. 33,48,943 (£251,800) in 1932, to 57,717 cwts. valued at Rs. 40,92,033 (£307,671) in 1933. The value for 1932 is the lowest total value recorded since 1915-16, when the value of the mica exports was £208,496. It is pleasant to be able to record the turning of the tide.

The difference between exports and production is generally attributed to theft from the mines. If this be the only explanation we must assume that during the three years prior to 1930 there had been as much mica stolen as won by honest means. Early in 1928 a bill was introduced into the Legislative Council of Bihar and Orissa, the purpose of which was an attempt to reduce the losses on this account by licensing miners and dealers; the bill was rejected. In March, 1930, however, a similar bill to regulate the possession and transport of, and trading in, mica was passed, and from the figures presented since 1930, as analysed above, it appears that this bill may have produced a good effect.

TABLE 24.—*Quantity and value of Mica produced in India during the years 1932 and 1933.*

—	1932.			1933.		
	Quantity.	Value (£1 = Rs. 13·3).		Quantity.	Value (£1 = Rs. 13·3).	
	Cwts.	Rs.	£	Cwts.	Rs.	£
Bihar and Orissa—						
Gaya	8,597	3,93,619	29,595	8,402	2,29,909	17,286
Hazaribagh . .	15,500	6,41,847	48,259	24,266	10,29,102	77,376
Monghyr	..	..	..	6	169	13
Madras—						
Nellore	8,318	3,82,056	28,726	7,932	3,97,462	29,884
Nilgiris	51	7,869	592	73	12,275	923
Rajputana—						
Ajmer-Merwara . .	177	6,510	490	326	10,128	762
Jaipur State . .	70	3,500	263	70	3,000	226
TOTAL .	32,713	*14,35,401*	*107,925*	41,075	*16,82,045*	*126,470*

TABLE 25.—*Quantity and value of Mica exported from India during the years 1932 and 1933.*

	1932.			1933.		
	Quantity.	Value (£1 = Rs. 13·8).		Quantity.	Value (£1 = Rs. 13·8).	
	Cwts.	Rs.	£	Cwts.	Rs.	£
To—						
United Kingdom	22,389	18,60,262	139,869	23,575	22,68,698	170,579
Ger any	5,013	2,39,505	18,008	6,161	3,20,961	24,132
France	788	87,719	6,595	1,067	79,831	6,002
United States of America.	11,264	5,44,569	40,945	19,812	8,94,321	67,242
Other countries	7,567	6,16,888	46,383	7,102	5,28,222	39,716
TOTAL	47,021	*33,48,943*	*251,800*	57,717	*40,92,033*	*307,671*

Monazite.

The monazite industry of Travancore, which was moribund in the year 1925, when the reported production was 1 cwt. only, showed signs of revival in 1926, the output amounting to 64·2 tons valued at £947. The production rose to 280 tons valued at £3,810 in 1927, fell to 103·4 tons valued at £1,242 in 1928, and rose again to 180 tons valued at £1,800 in 1929. In 1930 the production fell again heavily to 14 tons valued at £140, but in 1931 rose again to 89·6 tons, valued at £890, in 1932 to 654·3 tons valued at £6,147. Reliable figures for 1933 have not yet been received. The decline of the industry from the high figures of 1919 to 1921 is of course due to the supplanting of incandescent mantles for gas lighting by electricity. The increasing demand for ilmenite, occurring with the monazite and hitherto regarded as a bye-product, may be the means of reviving the industry by rendering cheaper production possible.

Nickel.

As a bye-product in the smelting operations of the Burma Corporation, Limited, at Namtu, in the Northern Shan States, there is now a regular production of nickel-speiss, which in 1927 amounted to 1,032 tons, in 1928 to 2,933 tons, in 1929 to 3,065 tons, and in

1930 to 3,150 tons. In 1931 the output fell somewhat to 2,911 tons valued at Rs. 6,73,973 (£49,924), rose in 1932 to 3,580 tons valued at Rs. 10,27,677 (£77,269), and fell again slightly in 1933 to 3,350 tons, valued at Rs. 10,28,523 (£77,333), and containing 29·04 per cent. of nickel, 11·0 per cent. of copper, and 26·60 ozs. of silver to the ton. This speiss is shipped to Hamburg for further treatment. It contains from 3 to 4 per cent. of cobalt.

Petroleum.

The world's production of petroleum in 1926 amounted to nearly 150 million long tons, of which India contributed 0·72 per cent. In 1927, this figure jumped to some 172 million long tons, of which the Indian proportion, on a practically stationary production, fell to 0·64 per cent. In 1928, there was another substantial rise in the world's production, which reached the figure of over 181 million tons. In 1929, there was another jump to over 202 million tons, but in 1930 the world's production fell to about 193½ million tons, in 1931 to about 187 million tons, and in 1932 to about 179 million tons, whilst in 1933 the production rose again to about 198 million tons. Decreases were shown by Columbia, Trinidad, India, Germany, Egypt and Canada. All other important producers showed an increase in production, by far the largest amount being due to the United States. The United States contributed 62·5 per cent. of the world's supply in 1933, Russia 10·6 per cent. and Venezuela 8·3 per cent. In 1928, India contributed 0·64 per cent., which fell to 0·60 per cent. in 1929 and rose to 0·62 in 1930, 0·63 per cent. in 1931 and 0·64 per cent. in 1932, and fell again to 0·62 per cent. in 1933; her position on the list of petroleum producing countries fell from 11th in 1929 to 12th in 1930 to 1933, her place being taken by Trinidad.[1]

The production of petroleum in India (including Burma) fell slightly from 308,606,031 gallons in 1932 to 306,009,022 gallons in 1933. The decrease in 1932 represents a considerable decrease in the output of Assam and the Punjab, and of a small proportionate decrease in the production of Burma. This decrease in output in 1933 was accompanied, however, by a large increase in value amounting to Rs. 1,18,24,818 (£889,084), or 23·3 per cent., an increase much

[1] Partly compiled from *The Petroleum Times* of 2nd June 1934.

in excess of the decrease of 1932 brought about by the world depression.

The amount of petrol produced from natural gas during the year was 8,729,928 gallons, of which 8,172,197 gallons were produced in Burma and 557,731 gallons in the Punjab.

The Yenangyaung field maintained its reputation of being one of the most wonderful oil fields in the world. The production of the previous year was not merely maintained, but was increased by 8,494,112 gallons, or nearly 7 per cent. of the 1932 total. New productive areas continue to be proved and the resources of the field as a whole are sufficient to ensure many further years of profitable production. At the end of 1933 there were 3,017 wells producing in the field. Besides a large number of wells drilled to shallow sands, this total includes 180 Burmese hand-dug wells whose continued existence is one of the interesting features of the field.

The bulk of the new production during the year continued to be derived from wells drilled on the eastern flank of the field outside the Reserves and their borders. Systematic exploration of this new area continued to make steady progress; at the end of the year its limits had not yet been reached. Within the Reserves and their borders flush production was obtained from deep sands in the eastern part of the Twingon Reserve and towards the end of the year competitive drilling by rotary methods commenced to the deep sands in the south-eastern part of the Beme Reserve. The search for new deep horizons continued, without success, as yet, but the progress of the deep test wells is being watched with interest.

The operation of the vacuum system in the Reserves and their borders remained unchanged. An order by the Warden, Burma Oilfields, permitting an increase to 7½ inches of mercury, and later to 10 inches of mercury, was reviewed by the Financial Commissioner, Burma. At the close of the year he passed an order restricting the areas in which the increased vacuum might be applied to the central and western part of each of the two Reserves where the majority of the wells which were in a late state of decline appeared to be segregated. The application of the increased vacuum was postponed until 1934 and provision was made for barrier zones between the areas of differential vacua within the Reserves and their borders.

Satisfactory results continue to be obtained from gas drives in the leased blocks. While the number of input wells has decreased,

the input of gas has been increased. The major companies operating within the Reserves cooperated in applying back pressures to youthful wells. Casing policies continue to be carefully designed to protect the oil sands against the danger of flooding by water and, in general, production methods throughout the field are characterised by a realisation of the importance of the conservation of oil and gas and the prevention of waste, whether simple or underground.

In 1933 there was a decrease of some 6 million gallons in the output of the Singu field, but a reduction in the total production obtained from this field does not necessarily indicate a corresponding decline in the productivity of the sands. At the end of the year the total number of producing wells was 448 as compared with 436 in December 1932. In addition a number of wells remained cemented above productive sands. These wells can be drilled into productive sands in a very short time and the total field production substantially increased.

There has been no radical change in production methods during the year under report. The fundamental principle underlying the policy of the major operating company is to make those adjustments at each well which lead to a maximum oil recovery with a minimum production of gas. Wells with high gas-oil ratios are shut in, and the balance of casing-head gas remaining after the satisfaction of the field requirements is returned to dry gas sands for storage, or to certain areas for repressuring purposes. There is one gas drive in operation and experiments in repressuring were undertaken by the British Burmah Petroleum Company, Ltd. At the close of the year this company had decided to apply an air drive to certain of their wells. During the year the Burmah Oil Company, Ltd., continued their preparations for the construction of a wall in the River Irrawaddy to reclaim a potentially productive area. Continuous gas-lift on some lower-division sand wells and gas-displacement pumping on upper-division sand wells were continued on a small scale, but production from the great majority of the wells in the field was obtained by ordinary pumping methods.

In 1933, the total production in the Pakokku district, excluding Lanywa, amounted to 4,224,958 gallons. No new horizons were proved during the year. The total production from the Lanywa field was virtually unchanged at 19,257,024 gallons. Steady progress was made with the work of filling in behind the embankment with the object of rendering the reclaimed area permanently above

highwater level. The embankment was extended and a further productive area proved behind the extension. Back pressures are maintained on nearly all the wells in this model field which is operated by the Indo-Burmah Petroleum Company, Ltd. All wells are pumped by electricity and pumping powers are about to be installed. The petrol plant was operated throughout the year and gave a satisfactory yield.

In the Minbu district there were, at the close of the year, 351 producing wells, including one gas well, giving a total production of 3,718,250 gallons. Apart from routine production there was very little activity in the district during the year.

In 1933 the total production from the Indaw field was restricted to 2,574,686 gallons. During the year the great majority of the wells at Indaw were successfully operated by the automatic gas lift system.

Production from the Padaukpin and Yenanma fields in the Thayetmyo district decreased by about 30,000 gallons during 1933. Towards the end of the year equipment for drilling under pressure was put into successful operation in the important deep test well which is being drilled by the Burmah Oil Company, Ltd., at Monatkon.

The output from Kyaukpyu remained as its usual low level.

Owing to the unfavourable economic conditions during 1932 and 1933 there was little activity in areas outside the producing fields of Burma.

In Assam there was a small decrease in the output of the Digboi field. No new areas have yet been proved in the Assam Valley.

In the Surma valley the Badarpur field was finally abandoned during the year and the output for the year was, therefore, small. Work at Patharia was temporarily suspended, while good progress was made with new drilling at Masimpur.

In the Punjab, the output from the Khaur field decreased by over 1,600,000 gallons. In a deep test well the underlying limestones were reached at about 5,600 feet from the surface and the boring was carried down to 5,877 feet. Small quantities of oil were found in the limestone, whilst indications of gas and oil were obtained from the strata immediately overlying the limestone. Another well is being deepened to test the value of these indications.

TABLE 26.—*Quantity and value of Petroleum produced in India during the years 1932 and 1933.*

—	1932.			1933.		
	Quantity.	Value (£1 = Rs. 13·3).		Quantity.	Value (£1 = Rs. 13·3).	
	Gals.	Rs.	£	Gals.	Rs.	£
Assam—						
Badarpur . .	847,217	63,357	4,764	55,867	4,178	314
Digboi . .	54,198,185	92,54,823	695,851	52,716,120	90,01,748	676,822
Patharia . .	89,854	7,919	595	..	..	..
Burma—						
Kyaukpyu . .	13,237	11,814	888	14,350	12,612	948
Minbu . .	3,850,716	6,25,750	47,049	3,718,250	7,90,218	59,415
Singu . .	88,941,939	1,44,53,065	1,086,697	82,613,112	1,75,55,284	1,319,946
Thayetmyo . .	464,826	75,453	5,673	434,572	92,346	6,943
Upper Chindwin .	4,040,690	3,03,051	22,786	3,052,778	2,28,958	17,215
Yenangyat (including Lanywa).	23,067,644	37,55,163	282,343	23,481,982	50,20,905	377,512
Yenangyaung .	127,191,743	2,07,65,523	1,561,318	135,685,855	2,88,50,573	2,169,216
Punjab—						
Attock . .	5,900,480	14,75,120	110,911	4,236,136	10,59,034	79,627
TOTAL .	**308,606,031**	*5,07,91,038*	*3,818,875*	**306,009,022**	*6,26,15,856*	*4,797,959*

TABLE 27.—*Imports of Kerosene Oil into India during the years 1932 and 1933.*

—	1932.			1933.		
	Quantity.	Value (£1 = Rs. 13·3).		Quantity.	Value (£1 = Rs. 13·3).	
	Gals.	Rs.	£	Gals.	Rs.	£
From—						
Union of Socialist Soviet Republics.	45,536,086	1,87,33,271	1,408,517	41,946,734	1,60,85.785	1,209,457
Roumania . .	4,919,489	23,01,891	173,074	6,216,529	15,55,280	116,938
Persia . . .	18,053,144	98,97,711	744,180	302,708	2,00,190	15,053
Straits Settlements	6,500	1,979	149	12	9	1
Borneo . .	2,181,860	8,72,149	65,575	..	..	..
Celebes and other Islands.	1,313,023	8,20,638	61,702	..	..	..
United States of America.	6,080,904	31,10,836	233,897	1,164,856	7,47,835	56,228
Other countries .	566	343	26	8,147,524	35,26,656	265,162
TOTAL .	**78,091,572**	*3,57,38,818*	*2,687,129*	**57,778,363**	*2,21,15,768*	*1,662,839*

TABLE 28.—*Imports of Fuel Oils into India during the years 1932 and 1933.*

	1932.			1933.		
	Quantity.	Value (£1 = Rs. 13·3).		Quantity.	Value (£1 = Rs. 13·3).	
	Gals.	Rs.	£	Gals.	Rs.	£
From—						
Roumania	2,917,087	5,53,871	41,644	8,767,246	16,09,411	121,008
Persia	67,938,453	1,31,09,255	985,658	64,584,911	1,23,24,390	926,646
Straits Settlements	69,899	19,314	1,452	150,389	41,706	3,136
Borneo	26,513,893	52,01,654	391,102	27,613,731	50,54,512	380,030
Other countries	7,813,355	15,42,640	115,988	3,852,481	7,94,256	59,718
TOTAL	105,252,687	*2,04,26,734*	*1,535,844*	104,968,758	*1,98,24,275*	*1,490,547*

TABLE 29.—*Exports of Paraffin Wax from India during the years 1932 and 1933.*

	1932.			1933.		
	Quantity.	Value (£1 = Rs. 13·3).		Quantity.	Value (£1 = Rs. 13·3).	
	Tons	Rs.	£	Tons	Rs.	£
To—						
United Kingdom	11,627	53,27,597	400,571	11,707	50,46,672	70,449
Germany	1,420	5,98,650	45,011	3,983	16,74,032	125,867
Netherlands	4,730	20,36,300	153,105	6,731	28,35,637	213,206
Belgium	3,501	15,11,800	113,669	4,347	18,57,704	139,677
Italy	4,030	16,92,600	127,263	4,525	18,84,426	141,686
China	2,000	8,67,440	65,222	1,490	7,68,600	57,790
Japan	1,795	7,90,300	59,421	210	1,17,600	8,842
Union of South Africa.	2,195	10,47,549	78,763	2,812	12,36,034	92,935
Portuguese East Africa.	4,619	24,09,785	181,187	4,681	21,35,369	160,554
Canada	1,270	5,33,400	40,105	1,950	8,18,800	61,564
United States of America.	3,950	16,59,000	124,737	5,074	21,28,930	160,070
Mexico	3,679	15,45,574	116,209	..	..	..
Chile	869	4,16,710	31,332	531	2,23,230	16,784
Australia	297	1,26,420	9,505	348	1,48,190	11,142
New Zealand	20	8,820	663	45	18,900	1,421
Argentine Republic	600	2,52,150	18,959	735	3,08,700	23,211
Straits Settlements	54	22,680	1,705	114	47,985	3,608
Other countries	452	1,91,020	14,362	2,480	10,42,580	78,389
TOTAL	47,198	*2,10,37,801*	*1,581,789*	51,768	*2,22,93,389*	*1,676,195*

There was a considerable decrease (20 million gallons) in the imports of kerosene, due mainly to an almost complete cessation of imports from Persia (18 million gallons), and a large fall in the imports from the United States of America (5 million gallons).

There was a trivial fall in the quantity of fuel oil imported into India, the principal change being an increase of nearly 6 million gallons from Roumania and a fall of some 3 million gallons from Persia. Some 62 per cent. of the supply was derived from Persia and some 26 per cent. from Borneo.

The exports of paraffin wax again showed an increase, amounting to some 4,500 tons (*See* Table 29).

Ruby, Sapphire and Spinel.

Since the liquidation of the Burma Ruby Mines, Limited, and the final cessation of the operations of this company in 1931, reliable statistics of production of gem stones in the Mogok Stone Tract have been unobtainable. Work is still continued by local miners, but of this no statistics are available; in addition a certain amount of work is being done under extraordinary licenses. For 1932 no returns are available, except that a fine ruby of 17 carats was found at Chaunggyi near Mogok, and a fine sapphire of about 90 carats and a good star sapphire of 453 carats were mined at Kathe. For 1933 the only return is of 1,103 carats of rubies from Kathe.

In addition the production was reported from Udhampur, Kashmir State, of 25,100 tolas (1,434,285 carats) of sapphire with corundum valued at Rs. 92,000 (£6,917). The sapphire deposits of Kashmir have long been known, but on account of their high altitude they are worked only occasionally.

TABLE 30.—*Quantity and value of Ruby and Sapphire produced in India during the years 1932 and 1933.*

—	1932.			1933.		
	Quantity.	Value (£1 = Rs. 13·3).		Quantity.	Value (£1 = Rs. 13·3).	
	Carats	Rs.	£	Carats	Rs.	£
Burma . . .	..	..	..	1,103 (Rubies)	583	44
Kashmir State . .	..	..	..	1,434,285 (Sapphire with corundum)	92,000	6,917
TOTAL .	..	..	..	1,435,388	*92,583*	*6,961*

Salt.

There was a substantial increase in the total output of salt, amounting to some 102,000 tons, shared by Madras (43,954 tons), Northern India (19,860 tons), Aden (16,888 tons), Burma (10,705 tons), and Bombay and Sind (10,124 tons). Imports of salt into India decreased largely by 155,923 tons, all the countries of origin showing decreases excepting Germany.

TABLE 31.—*Quantity and value of Salt produced in India during the years 1932 and 1933.*

—	1932.			1933.		
	Quantity.	Value (£1 = Rs. 13·3).		Quantity.	Value (£1 = Rs. 13·3).	
	Tons	Rs.	£	Tons	Rs.	£
Aden	291,241	32,24,898	242,474	308,129	21,00,096	157,902
Bombay and Sind	405,414	19,32,468	145,298	415,538	21,81,752	164,041
Burma	25,084	4,26,438	32,063	35,789	4,81,621	36,212
Gwalior	43	1,744	131	35	1,768	133
Madras	446,556	26,05,736	202,687	490,510	28,93,911	217,587
Northern India	442,523	36,72,149	276,101	462,383	37,65,718	283,137
TOTAL	1,610,861	*1,19,53,433*	*898,754*	1,712,384	*1,14,24,866*	*859,012*

TABLE 32.—*Quantity and value of Rock-Salt produced in India during the years 1932 and 1933.*

—	1932.			1933.		
	Quantity.	Value (£1 = Rs. 13·3).		Quantity.	Value (£1 = Rs. 13·3).	
	Tons	Rs.	£	Tons	Rs.	£
Salt Range	148,516	11,36,150	85,425	145,647	11,14,201	83,774
Kohat	19,972	62,796	4,721	20,577	65,116	4,896
Mandi	3,555	93,482	7,029	3,940	1,04,590	7,864
TOTAL	172,043	*12,92,428*	*97,175*	170,164	*12,83,907*	*96,534*

TABLE 33.—*Imports of Salt into India during the years 1932 and 1933.*

	1932.			1933.		
—	Quantity.	Value (£1 = Rs. 13·3).		Quantity.	Value (£1 = Rs. 13·3).	
	Tons	Rs.	£	Tons	Rs.	£
From— United Kingdom .	31,901	5,93,714	44,640	1,057	91,403	6,872
Germany . .	49,478	8,57,889	64,503	57,186	8,70,577	65,457
Spain . . .	25,994	3,72,953	28,042	7,725	1,33,185	10,014
Aden and Dependencies.	304,229	44,23,875	332,622	256,620	33,57,869	252,471
Egypt . . .	38,509	5,64,995	42,481	15,534	2,32,329	17,468
Italian East Africa	96,500	13,27,124	99,784	57,949	4,21,338	31,680
Other countries .	6,040	91,957	6,914	747	11,222	844
TOTAL .	552,741	*82,32,507*	*618,986*	396,818	*51,17,923*	*384,806*

Saltpetre.

Although statistics of production of saltpetre in India are no longer available, the export figures may be accepted as a fairly reliable index to the general state of the industry. Excepting a few hundreds of tons required for internal consumption as fertiliser, most of the output is exported to foreign countries. The quantity exported increased from 165,782 cwts. valued at Rs. 12,27,321 (£92,272) in 1932, to 189,567 cwts. valued at Rs. 15,57,919 (£117,136) in 1933.

A certain amount of nitrate of potash is used for agricultural purposes on the tea gardens of India. During the war, when it was impossible to obtain supplies of imported potash, the amount of locally produced nitrate utilised in this way reached an appreciable figure. The practice continued and the quantities estimated to have been absorbed for fertilising purposes on tea gardens in 1923, 1924, 1925, 1926, 1927, 1928, 1929, 1930, 1931 and 1932 were 1,000, 1,100, 800, 700, 500, 250, 300, 800, 680 and 730 tons respectively. In 1933, this figure is estimated to have been 450 tons only. The gradual decrease since the year 1925 is due to the fact that it was found cheaper to employ a mixture of imported sulphate of ammonia and nitrate of potash. The increased consumption in 1930 to 1932 was due to the nitrate being available at lower rates, and the decrease in 1933 to the general curtailment of manurial programmes due to economic conditions.

TABLE 34.—*Distribution of Saltpetre exported from India during the years 1932 and 1933.*

—	1932.			1933.		
	Quantity.	Value (£1 = Rs. 13·3).		Quantity.	Value (£1 = Rs. 13·3).	
	Cwts.	Rs.	£	Cwts.	Rs.	£
To—						
United Kingdom	55,832	4,25,567	31,997	59,834	5,07,289	38,142
Ceylon	36,373	2,09,327	15,739	16,439	1,10,912	8,339
Straits Settlements	3,346	42,031	3,160	3,338	44,345	3,334
Mauritius and Dependencies.	56,715	3,86,897	29,090	87,554	6,75,192	50,766
Other countries	13,516	1,63,499	12,286	22,402	2,20,181	16,555
TOTAL	165,782	*12,27,321*	*92,272*	189,567	*15,57,919*	*117,136*

Silver.

In contrast with the increases in the production of silver from the Bawdwin mines of Upper Burma, amounting to 1,400,291 ozs. recorded during the four years, 1925 to 1928, the following years 1929, 1930, and 1931 were marked by decreases amounting to 124,211 ozs., 226,311 ozs., and 1,153,806 ozs. respectively. In 1932 and 1933, however, there were small increases again, amounting to 98,556 ozs. and 53,504 ozs. respectively. These variations in quantity were accompanied by a small fall of value in 1929, marked falls in 1930 and 1931, and a marked rise in 1932, and a further rise in 1933.

The output of silver obtained as a bye-product from the Kolar gold mines of Mysore showed a fall of some 1,600 ozs.

The amount of silver bullion and coin exported during the year was 58,328,890 ozs. valued at Rs. 7,00,38,590 (£5,266,059) as compared with 34,664,148 ozs. valued at Rs. 4,15,61,144 (£3,124,898) during 1932.

TABLE 35.—*Quantity and value of Silver produced in India during the years 1932 and 1933.*

	1932.			1933.		
—	Quantity.	Value (£1 = Rs. 13·3).		Quantity.	Value (£1 = Rs. 13·3).	
	Ozs.	Rs.	£	Ozs.	Rs.	£
Bihar and Orissa— Manbhum . .	..	..	..	22	30	2
Burma— Northern Shan States.	5,998,956	62,32,915	468,640	6,054,047	65,74,695	494,338
Mysore— Kolar . . .	27,781	38,796	2,917	26,172	38,210	2,873
TOTAL .	6,026,737	*62,71,711*	*471,557*	6,080,241	*66,12,935*	*497,213*

Tin.

Following a series of years of practically continuous increase, a slight decrease in the production of tin-ore in Burma was reported for the year 1931, during which the output amounted to 4,255·2 tons valued at Rs. 35,07,380 (£259,806). In 1932, however, there was again an increase in production to 4,525 tons valued at Rs. 45,09,995 (£339,097), and in 1933 to 4,960·4 tons valued at Rs. 70,89,994 (£533,082). This is the highest quantity and total value yet recorded in any one year. The considerable increase in the total value is, of course, mainly due to the rise in the price of the metal resulting from the tin restriction scheme in operation in the five leading tin-producing countries Malaya, Netherlands East Indies, Bolivia, Nigeria and Siam, a scheme to which India is not an adherent. The increase in output of some 435 tons is the balance of an increase from Mergui and Mawchi in the Southern Shan States and a decrease from Tavoy. Milling operations were suspended at Mawchi in August 1927 pending the installation of additional plant and further development. Milling was resumed in February 1930 and this explains the large increases of 1930 to 1933. The total figure for 1933 includes 1,738·5 tons from Mawchi, calculated to be the proportion of tin-ore in 3,050 tons of concentrates derived from mixed wolfram-scheelite-cassiterite-ore; these concentrates are assumed to contain 43 per cent. of wolfram and 57 per cent. of cassiterite. There was no reported output of block tin.

Imports of unwrought tin fell from 49,279 cwts. valued at Rs. 47,50,341 (£357,168) in 1932 to 41,655 cwts. valued at Rs. 52,96,454 (£398,230) in 1933; over 97 per cent. of these imports came from the Straits Settlements.

TABLE 36.—*Quantity and value of Tin-ore produced in India during the years 1932 and 1933.*

—	1932.			1933.		
	Quantity.	Value (£1 = Rs. 13·3).		Quantity.	Value (£1 = Rs. 13·3).	
	Tons	Rs.	£	Tons	Rs.	£
Burma—						
Amherst . .	19·2	22,712	1,708	23·0	33,906	2,549
Mergui . .	598·0	5,44,332	40,927	978·7	12,71,204	95,579
Southern Shan States.	(a)1,557·3	15,52,129	116,701	(a)1,738·5	24,84,316	186,791
Tavoy . .	2,349·6	23,89,826	179,686	2,215·8	32,93,988	247,668
Thaton . .	0·9	996	75	4·4	6,580	495
TOTAL .	4,525·0	*45,09,995*	*339,097*	4,960·4	*70,89,994*	*533,082*

(a) Estimated.

TABLE 37.—*Imports of unwrought Tin (blocks, ingots, bars and slabs) into India during the years 1932 and 1933.*

—	1932.			1933.		
	Quantity.	Value (£1 = Rs. 13·3).		Quantity.	Value (£1 = Rs. 13·3).	
	Cwts.	Rs.	£	Cwts.	Rs.	£
From—						
United Kingdom .	773	74,419	5,595	1,024	1,21,170	9,111
Straits Settlements (including Labuan).	48,381	46,65,296	350,774	40,538	51,61,013	388,046
Other countries .	125	10,626	799	93	14,271	1,073
TOTAL .	49,279	*47,50,341*	*357,168*	41,655	*52,96,454*	*398,230*

Tungsten.

During the three years 1926 to 1928 there was a fall in the output of wolfram from 1,484 tons in 1926 to 622 tons in 1928, the last being valued at Rs. 2,99,549 (£22,354). In 1929, the output rose again to 1,348·4 tons valued at Rs. 15,16,795 (£113,193), and in 1930 to 2,451·5 tons valued at Rs. 18,09,881 (£134,065), declining slightly to 2,247·7 tons valued at Rs. 8,81,665 (£65,309) in 1931, and 2,022·9 tons valued at Rs. 7,03,852 (£52,921) in 1932, and rising again to 2,147·1 tons valued at Rs. 10,84,639 (£81,551) in 1933. The production of 1930 was the highest since the collapse of the industry at the end of the war and is close to the figure for 1920 (2,346·2 tons valued at £139,707) both in quantity and value. The figures for 1932 and 1933 include 1,174·8 tons and 1,311·5 tons respectively from Mawchi, calculated to be the proportion of wolfram in concentrates (assumed to contain 43 per cent. of wolfram and 57 per cent. of cassiterite) derived from the mixed wolfram-scheelite-cassiterite-ore.

The output of Tavoy rose slightly from 751·4 tons valued at Rs. 2,61,840 (£19,687) in 1932, to 762·1 tons valued at Rs. 3,96,354 (£29,801) in 1933.

TABLE 38.—*Quantity and value of Tungsten-ore produced in India during the years 1932 and 1933.*

—	1932.			1933.		
	Quantity.	Value (£1 = Rs. 13·3).		Quantity.	Value (£1 = Rs. 13·3).	
	Tons	Rs.	£	Tons	Rs.	£
Burma—						
Mergui . .	96·7	33,253	2,500	73·5	25,978	1,953
Southern Shan States.	1,174·8	4,08,759	30,734	1,311·5	6,62,307	49,797
Tavoy . .	751·4	2,61,840	19,687	762·1	3,96,354	29,801
TOTAL .	2,022·9	7,03,852	52,921	2,147·1	10,84,639	81,551

Zinc.

The production of zinc concentrates by the Burma Corporation, Limited, in the Northern Shan States, rose to 61,432 tons valued at Rs. 30,82,944 (£231,800) recovering thereby nearly all the ground

lost since 1928 (output 64,122 tons), though the value is still greatly below the value in the peak year namely £559,412 in 1928. The slight rise in the value per ton is parallel with a similar rise in the price of spelter. The exports during the year under review amounted to 64,050 tons valued at Rs. 32,02,500 (£240,789), against 49,950 tons valued at Rs. 24,97,500 (£187,782) in the preceding year.

Zircon.

The output of zircon, a mineral obtained as a concurrent product in the collection of ilmenite and monazite in Travancore State, increased from 490·6 tons valued at £3,805 in 1932 to 603 tons valued at £3,018 in 1933. There was a parallel decrease of ilmenite during the same year.

III.—MINERALS OF GROUP II.

Agate. The agate mines of Rajpipla State, Bombay Presidency, which had not been worked since 1917, were the source in 1929 of an output of 148·7 cwts. valued at Rs. 8,000 (£597). In the years 1930 to 1933 there was no production.

Alum. The output of alum in the Mianwali district, Punjab, amounted to only 478 cwts. valued at Rs. 5,525 (£412) in 1928. Since then there has been no manufacture owing to the low market rate.

Amber. The production of amber in the Myitkyina district, Burma, decreased from 29·5 cwts. valued at Rs. 12,020 (£897) in 1928, to 19·6 cwts. valued at Rs. 6,080 (£454) in 1929, and 2·1 cwts. valued at Rs. 730 (£54) in 1930. There was no reported output in 1931, but in 1932 there was an output of 11·5 cwts. valued at Rs. 1,940 (£146), and in 1933 of 76 lbs. valued at Rs. 1,500 (£113).

Apatite. The production of apatite in the Singhbhum district, Bihar and Orissa, was 22 tons valued at Rs. 3,300 (£244) in 1930, but *nil* in 1931, 1932 and 1933. The output of apatite in the Trichinopoly district, Madras, fell from 121 tons valued at Rs. 1,071 (£81) in 1932 to 37 tons valued at Rs. 372 (£28) in 1933.

Aquamarine. The last recorded output of aquamarine from the deposits of Daso in Ladakh in Kashmir was of 55 lbs. in 1921. In 1933 there was an output from these deposits of 686 tolas (39,000 carats) valued at Rs. 686 (£52).

Asbestos. There was a decrease in the total production of asbestos from 318·4 tons valued at Rs. 16,160 (£1,206) in 1929 to 33·2 tons valued at Rs. 1,190 (£88) in 1930. This was entirely derived from the Cuddapah district, Madras. The mines in Mysore and Seraikela State were not worked in 1930, and in 1931 the Cuddapah mines also ceased producing. A small output of 6 tons valued at Rs. 70 (£5) was reported from Ajmer-Merwara during 1931. In 1932 Seraikela State, Bihar and Orissa, yielded 90 tons of asbestos valued at Rs. 9,000 (£677). In 1933 there was no production of asbestos in India.

The production of barytes in India rose from 2,957 tons valued at Rs. 29,872 (£2,209) in 1932 to 5,651 tons valued at Rs. 41,517

(£3,122) in 1933, totals but slightly below those of 1931. This rise was largely due to the Cuddapah district, but there were also rises in Anantapur and Kurnool, offset by a decreased production in Alwar State, as is shown in Table 39.

Barytes.

TABLE 39.—*Quantity and value of Barytes produced in India during the years 1932 and 1933.*

—	1932.			1933.		
	Quantity.	Value (£1 = Rs. 13·3).		Quantity.	Value (£1 = Rs. 13·3).	
	Tons.	Rs.	£.	Tons.	Rs.	£.
Madras—						
Anantapur	166	1,726	129	216	2,045	154
Cuddapah	1,359	18,535	1,393	3,974	29,810	2,241
Kurnool	940	6,213	467	1,354	8,592	646
Rajputana—						
Alwar State	483	2,898	220	107	1,070	81
TOTAL	2,957	*29,372*	*2,209*	5,651	*41,517*	*3,122*

In 1930, 2,514 tons of bauxite valued at Rs. 20,112 (£1,490) were produced, of which 719 tons came from the Kaira district of Bombay, and 1,795 tons from the Jubbulpore district of the Central Provinces. In 1931 the output from the Jubbulpore district was 4,298 tons valued at Rs. 8,954 (£663), and in 1932 4,467 tons valued at Rs. 8,728 (£656). In 1933 there was an output of 1,075 tons valued at Rs. 3,150 (£237), of which 1,000 tons were produced in the Jubbulpore district, Central Provinces, and 75 tons in the Cuddapah district, Madras.

Bauxite.

In Jaipur State, Rajputana, 20 cwts. of beryl were extracted in 1930; no valued was reported. There was no output in 1931, but in 1932 there was a production in Ajmer-Merwara of 281 tons valued at Rs. 5,281 (£397) which rose to 324 tons valued at Rs. 7,261 (£546) in 1933.

Beryl.

This beryl is being shipped to Germany and the United States of America for use as beryllium-ore, *i.e.*, for the extraction of the metal. The Indian beryl is of high grade and fetches from £7 to £10 per ton c.i.f. in America and Europe, so that it is obviously under-valued in the returns. There appears to be no previous example of the production anywhere in the world of beryl on such a large scale.

Bismuth.

The production of native bismuth from the Tavoy district, Burma, fell from 112 lbs. valued at Rs. 323 (£24) in 1930, to 42 lbs. valued at Rs. 84 (£6) in 1931, and 27 lbs. valued at Rs. 54 (£4) in 1932; it rose again to 80 lbs. valued at Rs. 160 (£12) in 1933.

Borax.

Borax is sometimes produced from the Puga valley in the Ladakh *tahsil* of Kashmir State, the last reported production being of 7·3 cwts. in 1929.

Building materials and road-metal.

The total estimated value of building materials and road-metal produced in the year under consideration was Rs. 1,06,40,166 (£800,012). Certain returns supplied in cubic feet have been converted into tons on the basis of certain assumed relations between volume and weight.

Clays.

There was an increase in the recorded production of clays, which rose from 130,884 tons valued at Rs. 2,58,701 (£19,451) in 1932, to 230,002 tons valued at Rs. 2,17,882 (£16,382) in 1933. The largest increases were in Mysore, the Central Provinces, Bihar and Orissa, and the Punjab. There were no large falls.

TABLE 40.—*Production of Building Materials*

	Granite and Gneiss.		Laterite.		Lime.		Limestone and Kankar.	
	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.
	Tons.	Rs.	Tons.	Rs.	Tons.	Rs.	Tons.	Rs.
Assam . . .	8,339	26,479	34,366	22,075	..	..	65,464	1,09,432
Bengal . . .	212,265	1,45,859	..	..	..	..	..	..
Bihar and Orissa .	464,891	4,19,375	25	10	..	..	(a)705,598	14,46,855
Bombay . . .	..	..	2,977	3,971	..	..	128,260	81,000
Burma . . .	415,175	4,95,675	125,613	1,44,636	..	..	377,489	4,28,683
Central India . .	..	..	..	..	20,308	1,22,582	113,569	44,413
Central Provinces .	13,695	11,966	3,422	6,247	..	..	634,316	8,49,415
Gwalior . . .	..	..	..	..	..	..	49,734	23,330
Kashmir . .	..	..	..	..	..	..	..	..
Madras . . .	130,274	1,72,828	51,752	44,400	..	..	18,826	8,562
Mysore . . .	7,873	2,84,742	590	1,688	12,241	1,51,279	7,101	21,500
North-West Frontier Province.	..	..	..	..	..	..	996	2,470
Punjab . . .	281,060	2,49,153	..	..	..	..	172,916	1,58,568
Rajputana . .	..	..	..	..	..	..	(b)237,738	3,85,677
United Provinces .	52,890	1,18,854	..	..	..	..	(c)686,079	4,74,987
TOTAL .	1,586,462	*19,19,481*	218,745	*2,92,977*	32,549	*2,73,861*	3,143,026	*40,29,842*

(a) Includes 13,643 tons of dolomite.
(b) Includes 97 tons of dolomite.
(c) Includes 622,095 tons of *kankar*.

and Road-metal in India during the year 1933.

Marble.		Sandstone.		Slate.		Trap.		Miscellaneous.		Total value (£1 = Rs. 13·3).	
Quantity.	Value.	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.		
Tons.	Rs.	Tons.	Rs.	Tons.	Rs.	Tons.	Rs.	Tons.	Rs.	Rs.	£
..	..	12,357	21,955	..	..	..	..	253,775	3,49,206	5,29,147	39,785
..	..	..	..	..	..	..	..	16,700	12,525	1,57,884	11,871
..	..	33,830	41,283	1,812	46,256	125,717	1,20,538	93,684	49,993	21,24,316	159,723
..	..	..	..	..	..	306,866	4,62,668	40.674	38,315	5,85,954	44,057
..	..	87,097	1,08,898	..	..	..	..	861,055	8,33,669	20,06,561	150,869
..	..	..	..	..	..	..	..	2,768	1.610	1,68,605	12.677
..	..	..	..	..	..	..	..	33,054	25,585	8,93,218	67,159
..	..	7,509	11,599	..	..	..	..	..	..	34,929	2,626
..	..	..	..	..	..	..	..	141	90	90	7
..	..	..	..	..	..	2,490	3,161	800,373	2,83,498	5,12,449	38,530
..	..	..	..	8	40	..	..	195,424	1.24,025	5,83,224	43,851
..	..	..	..	..	..	..	..	3,349	4,592	7,062	531
..	..	..	..	6,509	1,27,747	..	..	4,479	5,526	5,40,994	40,676
4,752	1,61,709	190,303	6,44,281	1,157	7,700	..	..	50,931	72,690	12,72,057	95,643
..	..	15,967	13,309	1,891	8,644	..	..	342,789	6,12,943	12,23,687	92,007
4,752	*1,61,709*	347,063	*8,41,325*	11,377	*1,90,387*	[illegible]	*5,86,367*	[illegible]	*24,14,367*	*1,06,40,166*	*800,012*

TABLE 41.—*Production of Clays in India during the year 1933.*

—	1933.		
	Quantity.	Value (£1=Rs. 13·3).	
	Tons	Rs.	£
Assam	4,139	4,140	311
Bengal	8,296	6,249	470
Bihar and Orissa	32,319	1,08,650	8,169
Burma	19,365	23,615	1,776
Central India	404	1,500	113
Central Provinces	50,424	25,420	1,911
Delhi	5,342	3,038	228
Gwalior	462	1,730	130
Kashmir	7	23	2
Madras	12,076	6,602	496
Mysore	70,332	30,760	2,313
Punjab	25,347	3,960	298
Rajputana	1,489	2,195	165
TOTAL	230,002	*2,17,882*	*16,382*

Columbite.

An output of 100 lbs. of columbite valued at Rs. 60 (£4) was reported from the Monghyr district, Bihar and Orissa, during 1931. There was no output in 1932 and 1933.

Corundum.

The production of corundum in the Salem district, Madras, amounted to 30 tons valued at Rs. 2,189 (£162) in 1930, but there has been no production since.

Felspar.

There was an output in Ajmer-Merwara in 1933 of 677 tons of felspar valued at Rs. 5,877 (£442), against 473 tons valued at Rs. 4,388 (£330) in 1932.

Fuller's earth.

There was a further increase in the reported production of fuller's earth from 4,359 tons in 1932 to 7,257 tons in 1933. The increase was due to a large initial production from Khairpur State, Sind.

TABLE 42.—*Quantity and value of Fuller's Earth produced in India during the years 1932 and 1933.*

—	1932.			1933.		
	Quantity.	Value (£1=Rs. 13·3).		Quantity.	Value (£1=Rs. 13·2).	
	Tons.	Rs.	£.	Tons.	Rs.	£.
Bombay—						
Hyderabad (Sind) . .	789	13,416	1,008	688	14,035	1,055
Khairpur State (Sind) .	..	..	..	3,776	(*a*) 37,760	2,839
Central Provinces—						
Jubbulpore . . .	19	93	7	35	221	17
Rajputana—						
Bikaner State . . .	2,193	15,493	1,165	1,491	10,532	792
Jaisalmer State . . .	16	180	14	17	191	14
Jodhpur State . . .	1,342	16,100	1,211	1,250	15,000	1,128
TOTAL .	4,359	*45,282*	*3,405*	7,257	*77,739*	*5,845*

(*a*) Estimated.

Garnet. In 1933 there was an output of 295 tons of garnet sand valued at Rs. 2,950 (£222) in the Tinnevelly district, Madras, against an output of 147 tons in the previous year of which the value was not reported.

Graphite. There was an output of 6·5 tons of graphite in the Kistna district of Madras in 1931, whilst 5 tons of graphite were produced in 1932. There was no recorded output in 1933.

Gypsum. There was a marked fall in the output of gypsum from 51,421 tons valued at Rs. 86,342 (£6,491) in 1932 to 33,142 tons valued at Rs. 66,166 (£4,975) in 1933. The principal falls were in Bikaner State, Rajputana, and the Jhelum district, Punjab.

TABLE 43.—*Quantity and value of Gypsum produced in India during the years 1932 and 1933.*

—	1932.			1933.		
	Quantity.	Value (£1 = Rs. 13·3).		Quantity.	Value (£1 = Rs. 13·3).	
	Tons.	Rs.	£.	Tons.	Rs.	£.
Kashmir State	86	(a)	..	7	(a)	..
Madras—						
Trichinopoly	75	820	62	98	1,446	109
Punjab—						
Jhelum	12,726	13,150	988	9,221	9,780	735
Rajputana—						
Bikaner State	22,296	28,955	2,177	6,530	13,832	1,040
Jaisalmer State	235	913	69	272	1,083	81
Jodhpur State	16,000	42,500	3,195	17,000	40,000	3,008
United Provinces—						
Agra Garhwal	3	4	..	14	25	2
TOTAL	51,421	*86,342*	*6,491*	33,142	*66,166*	*4,975*

(a) Not reported.

Miscellaneous refractory minerals.

The output of kyanite and quartzite and related rocks in Bihar and Orissa is becoming increasingly important, partly for purposes of export, and partly for use in India, such as for furnace linings at Jamshedpur; but in 1931 there was a fall to a quarter of the 1930 output. In 1932 and 1933, however, there were again increases. The data for 1932 and 1933 which all relate to the Singhbhum district, except for 3 tons of kyanite produced in Ajmer-Merwara, Rajputana in 1932 and 17 tons of kyanite from the Mysore State in 1933, are assembled in Table 44, from which it will be seen that there has been an increase in total output from 14,173 tons valued at Rs. 1,34,706 (£10,103) in 1932 to 19,284 tons valued at Rs. 106,886 (£8,037) in 1933. The most valuable of these materials is kyanite extracted for export by the Indian Copper Corporation from Lopso Hill in Kharsawan.

TABLE 44.—*Quantity and value of Miscellaneous Refractory Materials produced in Bihar and Orissa during the years 1932 and 1933.*

—	1932.			1933.		
	Quantity.	Value (£1 = Rs. 13·3).		Quantity.	Value (£1 = Rs. 13·3).	
	Tons.	Rs.	£.	Tons.	Rs.	£.
Kyanite	(*a*) 5,580	91,227	6,834	(*b*) 4,283	69,432	5,220
Quartz-mica-schist . .	2,389	31,098	2,338	4,072	17,443	1,312
Quartzite	6,204	12,381	931	10,929	20,011	1,505
TOTAL .	14,173	*1,34,706*	*10,103*	19,284	*1,06,886*	*8,037*

(*a*) Includes 3 tons of kyanite produced in Ajmer-Merwara, Rajputana.
(*b*) Includes 17 tons of kyanite produced in Mysore State.

Ochre.

There was an increase in the production of ochre from 6,237 tons valued at Rs. 33,110 (£2,489) in 1932, to 11,630 tons valued at Rs. 60,895 (£4,578) in 1933. This increase is mainly due to Central India, and the Central Provinces, the two largest producers.

TABLE 45.—*Quantity and value of Ochre produced in India during the years 1932 and 1933.*

—	1932.			1933.		
	Quantity.	Value (£1 = Rs. 13·3).		Quantity.	Value (£1 = Rs. 13·3).	
	Tons.	Rs.	£.	Tons.	Rs.	£.
Central India . . .	1,857	15,274	1,148	5,315	42,082	3,164
Central Provinces . . .	3,365	9,747	733	5,118	11,334	852
Gwalior	403	3,27[illegible]	246	382	2,077	156
Madras	300	3,550	267	363	3,126	235
Rajputana	312	1,262	95	318	1,316	99
United Provinces . . .	..	..	..	134	960	72
TOTAL .	6,237	*33,110*	*2,489*	11,630	*60,895*	*4,578*

Pyrite.

There was an output of 23 tons of pyrite in Patiala State, Punjab, in 1930. The value was not reported. There has been no recorded output since.

Serpentine.

The figures of production of serpentine in the Skardu *tahsil*, Kashmir State, amounting to 1·8 tons valued at Rs. 75 (£6) reported for 1930, were identical with those for 1929 and 1928. The same value has been recorded in 1931, but the quantity produced has not been stated. No report has been received for 1932 or 1933.

Soda.

A production of 14·7 tons of soda valued at Rs. 533 (£39) was reported from the Ladakh *tahsil*, Kashmir State, in both 1929 and 1930. The output reported for 1928 was 11 tons valued at Rs. 533 (£40), in 1931, 11 tons valued at Rs. 412 (£31), and in 1932, also, 11 tons valued at Rs. 435 (£33). There was no reported production in 1933. Salt, consisting for the greater part of sodium carbonate, sodium bicarbonate and sodium chloride, used to be obtained by evaporation from the water of the Lonar Lake, in the Buldana district of Berar, in the Central Provinces. It was known under the general name of *trona* or *urao*, for which there is no suitable equivalent in English. The total amount of *trona* extracted in 1926 was 100 tons, the value of which was estimated at Rs. 3,000 (£224); as the company working the concession went into liquidation there has been no further reported production until 1930, for which the output was 100 tons valued at Rs. 950 (£70). This is the last recorded production.

Steatite.

There was a great increase in the production of steatite, which rose from 6,512 tons valued at Rs. 1,29,490 (£9,736) in 1932, to 17,048 tons valued at Rs. 1,82,964 (£13,757) in 1933. This rise was partly due to Jaipur State and the Jubbulpore, Hazaribagh, and Singhbhum districts, but principally to the United Provinces with a production increased from 314 tons in 1932 to 8,210 tons in 1933 mainly from the Hamirpur district, but partly from the Jhansi district.

TABLE 46.—*Quantity and value of Steatite produced in India during the years 1932 and 1933.*

——	1932.			1933.		
	Quantity.	Value (£1 = Rs. 13·3).		Quantity.	Value (£1 = Rs. 13·3).	
	Tons.	Rs.	£	Tons.	Rs.	£
Bihar and Orissa—						
Mayurbhanj State	..	..	..	6	578	43
Hazaribagh	..	..	..	452	6,000	451
Singhbhum	152	760	57	656	3,706	279
Central India—						
Bijawar State	110	2,430	183	60	2,700	203
Central Provinces—						
Jubbulpore	402	9,480	713	1,154	6,088	458
Madras—						
Nellore	41	1,909	143	30	1,650	124
Salem	179	2,855	215	214	3,365	253
Mysore State	133	542	41	115	814	61
Rajputana—						
Jaipur State	5,172	1,07,220	8,061	6,151	1,28,643	9,673
United Provinces—						
Hamirpur	314	4,294	323	7,275	25,429	1,912
Jhansi	..	..	..	935	3,991	300
TOTAL	6,512	*1,29,490*	*9,736*	17,048	*1,82,964*	*13,757*

Sulphate of Ammonia.

Until recently, figures of production of ammonium sulphate as a bye-product at the coking plants of iron and steel works and collieries have been collected only every five years for the quinquennial reviews of mineral production. They prove, however, to be of such general interest that it has been thought desirable to report them annually, and the figures for 1932 and 1933 are shown in Table 47. Values have not been obtained, and ammonium sulphate will not therefore find a place in Table I. The figures show a small increase in production from 9,474 tons in 1932 to 9,885 tons in 1933. The exports for these two years were 303 tons and 1,317 tons respectively.

TABLE 47.—*Production of Sulphate of Ammonia in India during the years 1932 and 1933.*

——	1932.	1933.
	Tons.	Tons.
The Tata Iron and Steel Co., Ltd.	5,304	5,288
The Indian Iron and Steel Co., Ltd.	2,271	2,172
The Burrakur Coal Co., Ltd.	736	1,325
The East India Railway Colliery, Giridih	253	219
The Bararee Coke Co., Ltd.	910	881
TOTAL	9,474	9,885

IV.—MINERAL CONCESSIONS GRANTED.

TABLE 48.—*Statement of Mineral Concessions granted during the year 1933.*

AJMER-MERWARA.

District.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Ajmer .	(1) Mr. Goverdhan Lal Rathi, Nasirabad.	Mica . . .	P. L. (Renewal).	8·8	25th August 1932.	1 year.
Do. .	(2) Mr. M. Mohamad Fazil, Ajmer.	Beryl-ore, felspar and quartz.	P. L. .	20·0	14th March 1933.	Do.
Do. .	(3) Mr. L. Prag Narain, Ajmer.	Felspar, china clay and mica.	P. L. .	0·8	30th March 1933.	Do.
Do. .	(4) Do. .	Mica and beryl .	P. L. .	1·4	Do. .	Do.
Do. .	(5) Do. .	Do. . .	P. L. .	2·8	8th June 1933.	Do.
Do. .	(6) Messrs. Abdul Ghani & Co., Nasirabad.	Mica . . .	P. L. (Renewal).	2·0	29th June 1933.	Do.
Do. .	(7) Mr. L. Prag Narain, Ajmer.	Beryl and felspar .	P. L. (Renewal).	0·7	10th August 1933.	Do.
Do. .	(8) Messrs. Abdul Ghani & Co., Nasirabad.	Mica . . .	M. L. .	5·7	1st February 1933.	3 years.
Do. .	(9) Mr. L. Goverdhan Lal Rathi, Nasirabad.	Do. . . .	M. L. .	1·0	21st September 1933.	Do.
Do. .	(10) Mr. L. Kanhiya Lal, Nasirabad.	Do. . . .	M. L. .	30·9	15th September 1933.	Do.
Beawar .	(11) Mr. L. Prag Narain, Ajmer.	Do. . . .	P. L .	6·6	2nd February 1933.	1 year.
ASSAM.						
Cachar .	(12) The Badarpur Oil Co., Ltd.	Mineral oil . .	P. L. .	157·4	1st November 1932.	2 years.
Do. .	(13) The Burmah Oil Co., Ltd.	Do. . .	P. L. .	6,169·6	6th April 1933.	1 year.
Do. .	(14) Do. .	Natural petroleum .	P. L. .	3,001·6	12th April 1933.	Do.
Do. .	(15) Do. .	Do. .	P. L. .	2,070·8	1st June 1933.	Do.
Lakhimpur .	(16) The Assam Oil Co., Ltd.	Petroleum . .	P. L. .	5,120·0	30th March 1933.	Do.
Do. .	(17) Do. .	Do. . .	P. L. .	3,968·0	12th May 1933.	Do.
Do. .	(18) Do. .	Do. . .	P. L. .	1,792·0	25th October 1933.	Until such time as a mining lease is granted.
Do. .	(19) Do. .	Do. . .	P. L. .	665·6	2nd May 1933.	Do.

P. L. = *Prospecting License.* M. L. = *Mining Lease.*

ASSAM—*contd.*

District.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Lakhimpur .	(20) The Assam Oil Co., Ltd.	Petroleum . .	P. L. .	590·7	31st December 1933.	1 year.
Do. .	(21) Do. .	Do. . .	P. L. .	6,016·0	8th October 1932.	2 years.
Sylhet .	(22) The Burmah Oil Co., Ltd.	Mineral oil . .	P. L. .	3,136·0	3rd May 1933.	1 year.
Do. .	(23) Do. .	Do. . .	P. L. .	2,861·6	3rd September 1933.	2 years.
Do. .	(24) Do. .	Do. . .	P. L. .	9,305·6	1st October 1933.	Do.

BALUCHISTAN.

District.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Kalat .	(25) Mr. F. B. Patel, St. John Steam Mills, Quetta.	Coal	P. L. .	1,280	9th October 1933.	1 year.
Do. .	(26) Mullick Wilayet Hussain, Shahrig.	Do.	P. L. .	1,440	6th November 1933.	Do.
Do. .	(27) P. Nanak Chand Chooni, Mohalla Ramgarh, Quetta.	Do.	M. L. .	160	1st July 1933	30 years.
Do. .	(28) Do. .	Do.	M. L. .	90	Do. .	Do.
Do. .	(29) Do. .	Do.	M. L. .	80	Do. .	Do.
Quetta-Pishin.	(30) Mian Muhammad Ismail, Mohalla Islamabad, Quetta.	Do.	M. L. .	150	1st January 1933.	Do.

BIHAR AND ORISSA.

District.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Hazaribagh	(31) Babu M. K. Roy .	Sillimanite, kyanite and abrasive garnet.	P. L. .	51·2	15th December 1933.	1 year.
Santal Parganas.	(32) Babu Bansi Ram Marwari.	Coal . . .	M. L. .	1·0	1st April 1933.	2 years.
Do. .	(33) Babu Ganga Ram Marwari.	Do. . . .	M. L. .	1·8	Do. .	Do.
Do. .	(34) Babu Subodh Chandra Roy.	Do. . . .	M. L. .	5·0	Do. .	Do.
Do. .	(35) Do. .	Do. . . .	M. L. .	1·6	Do. .	Do.
Do. .	(36) Do. .	Do. . . .	M. L. .	1·9	Do. .	Do.
Do. .	(37) Babu Hem Chandra Dey.	Do. . . .	M. L. .	2·2	Do. .	Do.
Do. .	(38) Babu Bansi Ram Marwari.	Do. . . .	M. L. .	1·0	Do. .	Do.
Do. .	(39) Do. .	Do. . . .	M. L. .	5·0	Do. .	Do.

P. L. = *Prospecting Licence.* M. L. = *Mining Lease.*

BIHAR AND ORISSA—*contd.*

District.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Santal Parganas.	(40) Babu Bansi Ram Marwari.	Coal . . .	M. L. .	5·0	1st April 1933.	2 years.
Do. .	(41) Do. .	Do. . . .	M. L. .	5·0	Do. .	Do.
Do. .	(42) Do. .	Do. . . .	M. L. .	5·0	Do. .	Do.
Do. .	(43) Do. .	Do. . . .	M. L. .	0·3	Do. .	Do.
Do. .	(44) Do. .	Do . . .	M. L. .	5·0	Do. .	Do.
Do. .	(45) Babu Rameswar Marwari.	Do. . . .	M. L. .	2·2	Do. .	Do.
Do. .	(46) Babu Bansi Ram Marwari.	Do. . . .	M. L. .	1·9	Do. .	Do.
Singhbhum .	(47) Babu Sushil Kumar.	Chromite . .	P. L. .	204·8	3rd May 1933	1 year.

BOMBAY.

District.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Belgaum .	(48) Messrs. Dalchand Bahadur Singh, Calcutta.	Bauxite . . .	P. L. .	558	14th July 1933.	3 years.
Ratnagiri .	(49) Messrs. Oakley Duncan & Co., Ltd., Bangalore.	Chromite . .	P. L. .	1,280	1st January 1933.	1 year.

BURMA.

District.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Akyab .	(50) Messrs. The Burmah Oil Co., Ltd.	Natural petroleum (including natural gas).	P. L. .	7,654·4	2nd November 1932.	2 years.
Do. .	(51) Do. .	Do. .	P. L. (Renewal).	2,944·0	18th April 1933.	1 year.
Do. .	(52) Messrs. The Indo-Burma Petroleum Co., Ltd.	Do. .	P. L. (Renewal).	1,177·6	22nd April 1933.	7 months and 23 days.
Amherst .	(53) Mr. Yee Ho Koon	All minerals except oil.	P. L. .	640·0	20th April 1933.	1 year.
Do. .	(54) Mr. Bhart Singh .	Do. .	P. L. .	320·0	27th October 1933.	Do.
Do. .	(55) Mr. Saw Fu Hoke	Do. .	P. L. .	1,920·0	18th December 1933.	Do.
Do. .	(56) U Ohn Pe . .	Do. .	P. L. (Renewal).	640·0	5th February 1933.	Do.
Lower Chindwin.	(57) Messrs. The Indo-Burma Petroleum Co., Ltd.	Natural petroleum (including natural gas).	P. L. (Renewal).	3,187·2	24th September 1933.	Do.
Magwe .	(58) Mr. B. C. P. Campbell.	Copper, gold, silver and allied minerals.	P. L. .	320·0	10th April 1933.	years.

P. L.=*Prospecting License.* M. L.=*Mining Lease.*

BURMA—*contd.*

District.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Magwe	(59) Messrs. The British Burmah Petroleum Co., Ltd.	Copper, gold, silver and allied minerals.	P. L.	1,196·8	19th September 1933.	2 years.
Do.	(60) Do.	Do.	P. L.	15,360·0	11th April 1933.	Do.
Do.	(61) Messrs. The Burmah Oil Co., Ltd.	Do.	M. L.	1,280·0	1st July 1933	30 years.
Do.	(62) Do.	Do.	P. L. (Renewal).	463·6	17th April 1933.	1 year.
Do.	(63) Do.	Natural petroleum (including natural gas).	P. L. (Renewal).	960·0	2nd September 1933.	Do.
Mergui	(64) Mr. Ah Khoon	Tin and allied minerals.	P. L.	51·2	9th January 1933.	Do.
Do.	(65) Do.	All minerals except mineral oil.	P. L.	620·8	10th May 1933.	Do.
Do.	(66) Mr. Kapur Singh	Tin and allied minerals.	P. L.	140·8	12th August 1933.	Do.
Do.	(67) Mr. Gul Mahomed	Tin and wolfram	P. L.	371·2	7th February 1933.	Do.
Do.	(68) Mr. Leslie R. Beale	Tin and allied minerals.	P. L.	505·6	28th February 1933.	Do.
Do.	(69) Mr. Saw Lein Lee	Do.	P. L.	448·0	19th January 1933.	Do.
Do.	(70) Mr. Ah Khoon	Tin-ore	P. L.	44·8	31st October 1933.	Do.
Do.	(71) Mr. Tan Teik Aik	Tin	P. L.	1,049·6	23rd January 1933.	Do.
Do.	(72) Maung Sein Shan	Do.	P. L.	339·2	7th September 1933.	Do.
Do.	(73) Mr. Leong Foke Hye.	Tin and wolfram	P. L.	268·8	6th March 1933.	Do.
Do.	(74) Mr. A. E. Ahmad.	Do.	P. L.	211·2	19th April 1933.	Do.
Do.	(75) Mr. Udhanders	Tin and other minerals	P. L.	275·2	11th September 1933.	Do.
Do.	(76) Mr. Ooi Kwee Ya	Tin-ore	P. L.	198·4	25th April 1933.	Do.
Do.	(77) U San Dun	Do.	P. L.	339·2	25th October 1933.	Do.
Do.	(78) Do.	Do.	P. L.	70·4	27th April 1933.	Do.
Do.	(79) Mr. A. Helleman	Tin and allied minerals.	P. L.	422·4	7th April 1933.	Do.
Do.	(80) Mr. Gul Mahamed	All minerals	P. L.	377·6	5th April 1933.	Do.

P. L.—*Prospecting License.* M. L.—*Mining Lease.*

BURMA—*contd.*

District.	Granted.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Mergui .	(81) Mr. A. S. Mahomed	Tin, wolfram and allied minerals.	P. L. .	339·2	2nd June 1933	1 year.
Do. .	(82) U San Dun .	Tin . . .	P. L. .	140·8	31st May 1933.	Do.
Do. .	(83) Mr. In Sit Yan .	Tin and other minerals.	P. L. .	294·4	13th May 1933.	Do.
Do. .	(84) Ma Hta Shwe .	Tin . . .	P. L. .	307·2	23rd June 1933.	Do.
Do. .	(85) Mr. A. E. Ahmed	Tin-ore and allied minerals.	P. L. .	243·2	5th June 1933	Do.
Do. .	(86) Mr. Tan Teik Aik	Tin . . .	P. L. .	217·6	15th May 1933.	Do.
Do. .	(87) Mr. Leong Foke Hye.	Tin and wolfram .	P. L. .	326·4	5th June 1933	Do.
Do. .	(88) Ma Tin . .	Tin and allied minerals.	P. L. .	153·6	21st July 1933.	Do.
Do. .	(89) Mr. In Sit Yan .	Tin and other minerals.	P. L. .	108·8	5th April 1933	Do.
Do. .	(90) Ma Tin . .	Tin and allied minerals.	P. L. .	192·0	28th June 1933.	Do.
Do. .	(91) Maung Hlaing Pu	Tin-ore . . .	P. L. .	832·0	24th June 1933.	Do.
Do. .	(92) U San Dun .	Do. . . .	P. L. .	588·8	25th October 1933.	Do.
Do. .	(93) Ma Hta Shwe .	Do. . . .	P. L. .	396·8	26th June 1933.	Do.
Do. .	(94) Mr. Gul Mahomed	Tin and allied minerals.	P. L. .	531·2	17th August 1933.	Do.
Do. .	(95) Mr. Tan Boon Hein	Tin-ore . . .	P. L. .	140·8	24th August 1933.	Do.
Do. .	(96) Mr. In Sit Yan .	Tin and other minerals.	P. L. .	268·8	2nd June 1933	Do.
Do. .	(97) Mr. John T. Doupe	Tin and allied minerals.	P. L. .	108·8	6th September 1933.	Do.
Do. .	(98) Mr. P. B. O. Watson.	Do. .	P. L. .	108·8	2nd August 1933.	Do.
Do. .	(99) Mr. Leong Foke Hye.	Do. .	P. L. .	614·4	27th September 1933.	Do.
Do. .	(100) U San Dun .	Tin-ore . . .	P. L. .	211·2	30th September 1933.	Do.
Do. .	(101) U Kyaing . .	Tin and allied minerals.	P. L. .	441·6	1st December 1933.	Do.
Do. .	(102) Mr. George W. Bowden.	Tin-ore . . .	P. L. .	556·8	17th May 1933.	Do.
Do. .	(103) Mr. A. S. Mahamad.	Wolfram and other allied minerals.	P. L. .	748·8	1st August 1933.	Do.

P. L. = *Prospecting Licence.*

BURMA—*contd.*

District.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Mergui .	(104) Mr. A. S. Mahamad.	Tin and other allied metals.	P. L. .	640·0	17th July 1933.	1 year.
Do. .	(105) Maung Hlaing Pu.	Tin-ore . . .	P. L. .	275·2	18th August 1933.	Do.
Do. .	(106) Maung Chit Po .	Do. . . .	P. L. .	595·2	19th September 1933.	Do.
Do. .	(107) Ma Tin . .	Tin and allied minerals.	P. L. .	108·8	14th October 1933.	Do.
Do. .	(108) Mr. Leslie R. Beale.	Tin and allied minerals.	P. L. .	582·4	30th September 1933.	Do.
Do. .	(109) Mr. Hta Shwe .	All minerals except oil.	P. L. .	345·6	25th September 1933.	Do.
Do. .	(110) U San Dun .	Tin . . .	P. L. .	1,132·8	27th September 1933.	Do.
Do. .	(111) Mr. Ah Shee .	Tin and allied minerals.	P. L. .	236·8	13th October 1933.	Do.
Do. .	(112) Mr. A. S. Mahomed.	Do. .	P. L. .	326·8	6th September 1933.	Do.
Do. .	(113) Maung Chit Po .	Tin . . .	P. L. .	185·6	17th November 1933.	Do.
Do. .	(114) Mr. Tan Shu En.	Tin and allied minerals.	P. L. .	320·0	13th September 1933.	Do.
Do. .	(115) Mr. A. Helleman	Do. .	P. L. .	76·8	17th November 1933.	Do.
Do. .	(116) Mr. Soon Na .	Tin . . .	P. L. .	377·6	5th December 1933.	Do.
Do. .	(117) Mr. Tan Saing Shin.	Do. . . .	P. L. .	185·6	13th September 1933.	Do.
Do. .	(118) Mr. Eu Gwan Kyin.	Do. . . .	P. L. .	198·4	18th November 1933.	Do.
Do. .	(119) Mr. Ah Yee .	Do. . . .	P. L. .	352·0	20th October 1933.	Do.
Do. .	(120) Mr. A. S. Mahomed.	Tin, wolfram and other allied minerals.	P. L. .	771·2	21st November 1933.	Do.
Do. .	(121) Mr. Eng Tain Leong.	Tin-ore . . .	P. L. .	198·4	25th October 1933.	Do.
Do. .	(122) Mr. George W. Bowden.	Tin and all minerals except coal and oil.	P. L. .	320·0	30th September 1933.	Do.
Do. .	(123) Do. .	Do. .	P. L. .	608·0	17th August 1933.	Do.
Do. .	(124) Mr. Tan Shue En	Tin and allied minerals.	P. L. .	307·2	28th November 1933.	Do.
Do. .	(125) Mr. Tan Teik Aik	Tin . . .	P. L. .	876·8	22nd August 1933.	Do.
Do. .	(126) Maung Kyin Haing.	Tin and allied minerals.	P. L. .	544·0	9th December 1933.	Do.

P. L.=*Prospecting License*, M. L.=*Mining Lease.*

BURMA—*contd.*

District.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Mergui .	(127) Saw Maung Po .	Tin . . .	P. L. .	147·2	22nd December 1933.	1 year.
Do. .	(128) Do. .	Do. . . .	P. L. .	396·8	Do. .	Do.
Do. .	(129) Mr. A. S. Mahomed.	Tin and allied minerals.	P. L. .	256·0	16th December 1933.	Do.
Do. .	(130) Mr. Leslie R. Beale.	Do. .	P. L. .	217·6	16th November 1933.	Do.
Do. .	(131) Mr. Leong Foke Hye.	Do. .	P. L. .	390·4	14th December 1933.	Do.
Do. .	(132) Mr. Eu Gwan Kyin.	Tin-ore . . .	P. L. .	211·2	18th November 1933.	Do.
Do. .	(133) U. E. Gyi . .	Tin and allied minerals.	M. L. .	102·4	1st August 1933.	30 years.
Do. .	(134) Mr. Eng Tain Leong.	Tin-ore . . .	M. L. .	70·4	1st April 1933	Do.
Do. .	(135) Mr. E. Maxwell Lefroy.	Tin-ore and allied minerals.	M. L. .	390·4	1st October 1933.	Do.
Do. .	(136) Mr. Lim Oo Ghino.	Tin and allied minerals.	P. L. . (Renewal).	1,113·6	18th January 1933.	1 year.
Do. .	(137) U Po Thaik .	Tin and wolfram .	P. L. . (Renewal).	160·0	2nd February 1933.	Do.
Do. .	(138) Mr. G. H. Hand .	Gold, tin and allied minerals.	P. L. . (Renewal).	390·4	26th February 1933.	Do.
Do. .	(139) Mr. Leong Foke Hye.	Tin and wolfram .	P. L. . (Renewal).	384·0	18th April 1933.	Do.
Do. .	(140) Maung Sein Shan	Tin and allied minerals.	P. L. . (Renewal).	384·0	17th March 1933.	Do.
Do. .	(141) Mr. F. Wah Yu .	Do. .	P. L. . (Renewal).	480·0	Do. .	Do.
Do. .	(142) U E Gyi . .	Do. .	P. L. . (Renewal).	102·4	19th March 1933.	Do.
Do. .	(143) Mr. Eng Tain Leong.	Do. .	P. L. . (Renewal).	192·0	26th March 1933.	Do.
Do. .	(144) U San Dun .	Tin . . .	P. L. . (Renewal).	486·4	11th April 1933.	Do.
Do. .	(145) Mr. Kapur Singh	Do. . . .	P. L. . (Renewal).	889·6	7th May 1933	Do.
Do. .	(146) U San Dun .	Tin and allied minerals.	P. L. . (Renewal).	140·8	11th May 1933	Do.
Do. .	(147) Mr. Leong Foke Hye.	Tin, wolfram and other allied minerals.	P. L. . (Renewal).	281·0	14th May 1933	Do.
Do. .	(148) Maung Hlaing Pu	Tin and allied minerals.	P. L. . (Renewal).	230·4	1st July 1933	Do.
Do. .	(149) Do. .	Do. .	P. L. . (Renewal).	153·6	Do. .	Do.

P. L. = *Prospecting License*, M. L. = *Mining Lease*.

BURMA—*contd.*

District.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Mergui .	(150) Mr. M. Haniff .	Tin and allied minerals.	P. L. (Renewal).	243·2	1st July 1933	1 year.
Do. .	(151) Maung Hlaing Pu	Do. .	P. L. (Renewal).	358·4	13th July 1933.	Do.
Do. .	(152) U Po Thaik .	Tin . . .	P. L. (Renewal).	595·2	10th August 1933.	Do.
Do. .	(153) Mr. Udhandas .	Tin and allied minerals.	P. L. (Renewal).	467·2	16th August 1933.	Do.
Do. .	(154) Mr. E. Ahmed .	Do. .	P. L. (Renewal).	275·2	24th August 1933.	Do.
Do. .	(155) Mr. Udhandas .	Do. .	P. L. (Renewal).	550·4	21st September 1933.	Do.
Do. .	(156) Do. .	Do. .	P. L. (Renewal).	211·2	14th September 1933.	Do.
Do. .	(157) Do. .	Do. .	P. L. (Renewal).	422·1	Do. .	Do.
Do. .	(158) Mr. Eu Gwan Kyin.	Do. .	P. L. (Renewal).	691·2	15th September 1933.	Do.
Do. .	(159) Mr. Eng Tain Leong.	Tin-ore . . .	P. L. (Renewal).	179·2	20th October 1933.	Do.
Do. .	(160) Messrs. The Malayan and General Trust, Ltd.	Do. . . .	P. L. (Renewal).	179·2	25th July 1933.	Do.
Do. .	(161) Mr. Ah Khoon .	Do. . . .	P. L. (Renewal).	76·8	26th September 1933.	Do.
Do. .	(162) Mr. Neil Gow .	Do. . . .	P. L. (Renewal).	1,587·2	4th November 1933.	Do.
Do. .	(163) Mr. Chan Kee .	All minerals except oil.	P. L. (Renewal).	576·0	16th September 1933.	Do.
Do. .	(164) Mr. Tan Boon Hein.	Tin-ore . . .	P. L. (Renewal).	102·4	4th November 1933.	Do.
Minbu .	(165) U Soe Thein (Twinza).	Natural petroleum (including natural gas), coal and other minerals.	P. L. .	1,280·0	28th October 1933.	Do.
Do. .	(166) Messrs. The Burmah Oil Co., Ltd.	Natural petroleum (including natural gas).	P. L. .	80·0	10th May 1933	Do.
Myingyan .	(167) Messrs. The Yenangyaung Oilfield Southern Extension, Ltd.	Do. .	P. L. (Renewal).	1,280·0	27th September 1933.	Do.
Do. .	(168) Dr. A. W. G. Bleeck	Do. .	P. L. (Renewal).	640·0	15th January 1933.	Do.
Myitkyina .	(169) Messrs. A. H. Miles and T. L. Willan.	Gold and platinum .	P. L. .	1,600·0	20th July 1933	Do.
Do. .	(170) Do. .	Do. .	P. L. .	1,600·0	3rd August 1933.	Do.

P. L. = *Prospecting License.*

BURMA—*contd.*

District.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Myitkyina .	(171) Messrs. A. H. Miles and T. L. Willan	Gold and platinum.	P. L. .	1,600·0	3rd August 1933.	1 year.
Northern Shan States.	(172) Messrs. The Burma Corporation, Ltd.	All minerals . .	P. L. .	2,457·6	16th February 1933.	Do.
Do. .	(173) Mr. A. R. Oberlander.	Lead and silver .	P. L. .	1,680·0	4th March 1933.	Do.
Do. .	(174) Hkun Pan Sing, Sawbwa of Tawngpeng.	All minerals . .	P. L. .	640·0	3rd August 1933.	Do.
Do. .	(175) Do. .	Do. . .	P. L. .	480·0	Do. .	Do.
Do. .	(176) Do. .	Do. . .	P. L. .	640·0	Do. .	Do.
Do. .	(177) Do. .	Do. . .	P. L. .	1,280·0	Do. .	Do.
Do. .	(178) Do. .	Do. . .	P. L. .	640·0	Do. .	Do.
Do. .	(179) Do. .	Do. . .	P. L. .	1,280·0	Do. .	Do.
Do. .	(180) Do. .	Do. . .	P. L. .	640·0	Do. .	Do.
Do. .	(181) Do. .	Do. . .	P. L. .	1,280·0	Do. .	Do.
Do. .	(182) Do. .	Do. . .	P. L. .	800·0	3rd November 1933.	Do.
Do. .	(183) Mr. A. R. Oberlander.	Lead, silver, zinc and copper.	M. L. .	320·0	1st December 1933.	30 years.
Do. .	(184) Messrs. The Burma Corporation, Ltd.	Iron-ore . . .	M. L. .	37·7	16th January 1933.	Do.
Pakokku .	(185) U. Myat San .	Natural petroleum (including natural gas).	P. L. .	102·4	23rd February 1933.	2 years
Do. .	(186) Messrs. The Burmah Oil Company, Ltd.	Do. .	P. L. .	164·0	14th December 1933.	Do.
Do. .	(187) Do. .	Do. .	P. L. . (Renewal).	320·0	24th April 1933.	1 year.
Salween .	(188) Daw Hta Shwe .	All minerals except mineral oil.	P. L. .	640·0	1st September 1933.	Do.
Southern Shan States.	(189) Mr. E. C. M. Garrett.	Do. .	P. L. .	6,246·4	20th September 1933.	Do.
Do. .	(190) Do. .	Do. .	P. L. .	3,328·0	30th October 1933.	Do.
Do. .	(191) Mr. Abdul Haq .	Wolfram. . .	P. L. .	640·0	12th December 1933.	Do.
Do. .	(192) Mr. E. C. M. Garrett.	All minerals except mineral oil.	P. L. .	1,414·4	20th February 1933.	Do.
Do. .	(193) Do. .	Do. .	P. L. . (Renewal).	960·0	12th October 1933.	Do.

P. L.—*Prospecting License.* M. L.—*Mining Lease.*

BURMA—*contd.*

District.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Southern Shan States.	(194) Mr. E. C. M. Garrett.	All minerals except mineral oil.	P. L. (Renewal).	704·0	20th September 1933.	1 year.
Do.	(195) Do.	Do.	P. L. (Renewal).	12·8	29th March 1933.	Do.
Thaton	(196) U. Tha Htu	All minerals except oil.	P. L.	569·6	28th September 1933.	Do.
Do.	(197) Do.	Do.	P. L.	640·0	Do.	Do.
Do.	(198) Mr. A. J. Beale	Do.	P. L.	992·0	17th October 1933.	Do.
Do.	(199) Mr. B. R. Fernandez.	Do.	P. L.	486·4	17th June 1933.	Do.
Thayetmyo.	(200) Messrs. The Indo-Burma Oil Fields (1920), Ltd.	Natural petroleum (including natural gas).	M. L.	320·0	8th March 1933.	30 years.
Do.	(201) Mr. W. R. Smith	Do.	P. L. (Renewal).	108·8	16th August 1932.	1 year.
Do.	(202) Messrs. The Irrawaddy Petroleum Oil Syndicate, Ltd.	Do.	P. L. (Renewal).	320·0	5th October 1932.	Do.
Do.	(203) Messrs. The Burmah Oil Co., Ltd.	Do.	P. L. (Renewal).	1,676·8	7th January 1933.	Do.
Do.	(204) Do.	Do.	P. L. (Renewal)	2,240·0	23rd March 1933	Do.
Do.	(205) Do.	Do.	P. L. (Renewal).	2,457·6	30th June 1933.	Do.
Tavoy	(206) Mr. Lim Toe Yin	Tin and wolfram	P. L.	640·0	26th April 1933.	Do.
Do.	(207) Mr. D. R. Bowrie	Do.	P. L.	640·0	1st March 1933.	Do.
Do.	(208) Mr. H. G. Gregson	Do.	P. L.	57·6	16th June 1933.	Do.
Do.	(209) Mr. Quah Cheng Guan.	Do.	P. L.	240·0	23rd January 1933.	Do.
Do.	(210) Messrs. The Consolidated Tin Mines of Burma, Ltd.	Do.	P. L.	256·0	21st January 1933.	Do.
Do.	(211) Mr. C. Soo Don	Do.	P. L.	204·8	15th June 1933.	Do.
Do.	(212) Mr. H. G. Gregson	Do.	P. L.	38·4	3rd April 1933.	Do.
Do.	(213) Mr. Teh Lu Pe	Tin and allied minerals.	P. L.	403·2	28th February 1933.	Do.
Do.	(214) Mr. Quah Hun Cheong.	All minerals except oil.	P. L.	320·0	Do.	Do.
Do.	(215) Mr. H. G. Gregson	Tin and wolfram	P. L.	140·8	28th April 1933.	Do.

P. L.—*Prospecting License.* M. L.—*Mining Lease.*

BURMA—*contd.*

District.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Tavoy .	(216) Messrs. The Tavoy Tin Dredging Corporation, Ltd.	All minerals other than oil.	P. L. .	396·8	17th January 1933.	1 year.
Do. .	(217) Mr. V. A. Ross Sutherland.	Tin and allied minerals.	P. L. .	121·6	5th June 1933.	Do.
Do. .	(218) Daw Thi . .	All minerals except oil.	P. L. .	960·0	22nd May 1933	Do.
Do. .	(219) Mr. Quah Hun Cheong.	Do. .	P. L. .	268·8	22nd April 1933.	Do.
Do. .	(220) Mr. Teh Lu Po .	Do. .	P. L. .	460·8	28th February 1933.	Do.
Do. .	(221) Do. .	Tin and allied minerals.	P. L. .	128·0	19th April 1933.	Do.
Do. .	(222) Mr. Chan Kee .	Do. .	P. L. .	428·8	20th May 1933	Do.
Do. .	(223) Mr. C. Soo Don .	All minerals except oil.	P. L. .	313·6	15th June 1933.	Do.
Do. .	(224) U Lu Nyo .	Do. .	P. L. .	704·0	19th April 1933.	Do.
Do. .	(225) Mr. H. G. Gregson	Do. .	P. L. .	1,088·0	3rd July 1933	Do.
Do. .	(226) Mr. Teh Lu Pe .	Do. .	P. L. .	1,216·0	5th June 1933	Do.
Do. .	(227) Do. .	Do. .	P. L. .	1,472·0	18th August 1933.	Do
Do. .	(228) Mr. Chan Kee .	Tin and wolfram .	P. L. .	640·0	3rd July 1933	Do.
Do. .	(229) Mr. Teh Lu Po .	Do. .	P. L. .	1,088·0	20th July 1933	Do.
Do. .	(230) U Lu Nyo .	All minerals except oil.	P. L. .	640·0	21st September 1933.	Do.
Do. .	(231) Mr. Chan Kee .	Do. .	P. L. .	507·5	24th July 1933	Do.
Do. .	(232) U Saw Pe . .	Tin and wolfram .	P. L. .	2,560·0	3rd September 1933.	Do.
Do. .	(233) U Lu Nyo .	All minerals except oil.	P. L. .	428·8	21st September 1933.	Do.
Do. .	(234) Mr. Chan Kee .	Do. .	P. L. .	640·0	3rd August 1933.	Do.
Do. .	(235) U Ohn Nyun .	Wolfram ore . .	M. L. .	96·0	15th November 1932.	30 years.
Do. .	(236) Do. .	Tin-ore	M. L. .	153·6	Do. .	Do.
Do. .	(237) Do. .	Do.	M. L. .	83·2	1st May 1933.	Do.
Do. .	(238) Mr. H. G. Gregson	Tin and wolfram .	M. L. .	134·4	1st February 1933.	Do.
Do. .	(239) Messrs. The Consolidated Tin Mines of Burma, Ltd.	Do. .	M. L. .	51·2	1st August 1933.	Do.
Do. .	(240) Mr. Teh Lu Po .	Do. .	P. L. (Renewal). .	1,216·0	2nd January 1933.	1 year.

P. L.=*Prospecting License.* M. L.=*Mining Lease.*

BURMA—*contd.*

District.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Tavoy .	(241) Mr. Teh Lu Po .	Tin and wolfram .	P. L. (Renewal).	499·2	10th February 1933.	1 year.
Do. .	(242) U Kyaing . .	Do. .	P. L. (Renewal).	704·0	20th April 1933.	Do.
Do. .	(243) Mr. H. G. Gregson	Do. .	P. L. (Renewal).	108·8	21st May 1933	Do.
Do. .	(244) U Ohn Nyun .	Do. .	P. L. (Renewal).	96·0	7th March 1933.	Do.
Do. .	(245) Mr. Teh Lu Po .	Do. .	P. L. (Renewal).	204·8	23rd May 1933	Do.
Do. .	(246) Mr. D. B. Bowrie	Do. .	P. L. (Renewal).	640·0	2nd July 1933	Do.
Do. .	(247) Mr. Teh Lu Po .	Do. .	P. L. (Renewal).	486·4	14th July 1933	Do.
Do. .	(248) U Ohn Nyun .	Do. .	P. L. (Renewal).	198·4	7th July 1933	Do.
Do. .	(249) Daw Thi . .	Do. .	P. L. (Renewal).	832·0	27th July 1933	Do.
Do. .	(250) Mr. L. W. Elsum	Do. .	P. L. (Renewal).	224·0	17th August 1933.	Do.
Do. .	(251) Mr. H. G. Gregson	Do. .	P. L. (Renewal).	96·0	26th August 1933.	Do.
Do. .	(252) Mr. C. Soo Don .	Do. .	P. L. (Renewal).	147·2	24th October 1933.	Do.
Upper Chindwin.	(253) Messrs. The Burmah Oil Co., Ltd.	Natural petroleum (including natural gas).	P. L. .	8,320·0	25th June 1933.	2 years.
Do. .	(254) Messrs. Fairweather Richards & Co., Ltd.	Coal	P. L. (Renewal).	704·0	11th March 1933.	1 year.
Do. .	(255) Messrs. The Indo-Burma Petroleum Co., Ltd.	Natural petroleum (including natural gas).	P. L. (Renewal).	2,830·3	2nd August 1933.	Do.
Do. .	(256) Do. .	Do. .	P. L. (Renewal).	640·0	6th October 1933.	Do.
Do. .	(257) Messrs. Fairweather Richards & Co., Ltd.	Coal . . .	P. L. (Renewal).	561·2	15th August 1933.	Do.
Yamethin .	(258) Mr. M. A. Haq .	Wolfram and mixed ores.	P. L. .	640·0	22nd April 1933.	Do.
Do. .	(259) Mr. E. C. M. Garrett.	All minerals except oil and precious stones.	P. L. .	1,344·0	1st September 1933.	Do.
Do. .	(260) Mr. Saw Lein Lee	All minerals except mineral oil.	P. L. .	640·0	15th July 1933	Do.
Do. .	(261) Do. .	Do. .	P. L. .	640·0	Do. .	Do.
Do. .	(262) Do. .	Do. .	P. L. .	640·0	Do. .	Do.

P. L.=Prospecting License.

BURMA—*concld.*

District.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Yamethin .	(263) Mr. E. C. M. Garrett.	All minerals except oil and precious stones.	P. L. .	236·8	1st September 1933.	1 year.
Do. .	(264) Mr. Syed Ebrahim	All minerals except mineral oil.	P. L. .	640·0	31st August 1933.	Do.

CENTRAL PROVINCES.

District.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Balaghat .	(265) Mr. Kanhaiyalal of Balaghat.	Manganese . .	P. L. .	388	26th October 1933.	1 year.
Do. .	(266) The Central Provinces Manganese Ore Co., Ltd., Nagpur.	Do. . .	M. L. .	62	6th February 1933.	30 years.
Do. .	(267) Do. .	Do. . .	M. L. .	415	Do. .	Do.
Do. .	(268) Do. .	Do. . .	M. L. .	11	Do. .	Do.
Do. .	(269) Do. .	Do. . .	M. L. .	1,000	Do. .	Do.
Do. .	(270) Do. .	Do. . .	M. L. .	534	10th October 1933.	Do.
Do. .	(271) Do. .	Do. . .	M. L. .	85	Do. .	Do.
Bhandara .	(272) Mr. M. D'Costa, Nagpur.	Corundum and kyanite.	P. L. .	91	11th April 1933.	1 year.
Do. .	(273) Do. .	Do. .	P. L. .	12	Do. .	Do.
Do. .	(274) The Central Provinces Manganese Ore Co., Ltd., Nagpur.	Manganese-ore .	M. L. .	106	1st July 1933.	30 years.
Do. .	(275) Do. .	Do. .	M. L. .	363	Do. .	Do.
Do. .	(276) Mr. M. D'Costa, Nagpur.	China clay . .	P. L. .	47	11th April 1933.	1 year.
Do. .	(277) Mr. S. Kunwar Lal Singh, Phoolchur.	Sand . . .	Q. L. .	45	15th March 1933.	10 years.
Do. .	(278) Mr. Nandlal, Contractor, Gondia.	Clay . . .	Q. L. .	7	1st February 1933.	Do.
Do. .	(279) Messrs. Ganpat Rao Laxman Rao of Nagpur.	Flooring stone .	Q. L. .	4	26th May 1933	Do.
Do. .	(280) Mr. Tima Kasiram Mahar, Gondia.	Clay and sand .	Q. L. .	1	8th August 1933.	5 years.
Bilaspur .	(281) Mr. Jairam Valjee, Contractor of Raigarh.	Limestone . .	Q. L. .	18	26th August 1932.	10 years.
Do. .	(282) Messrs. Gurubux Singh, Uttamsingh & Co., Torwa.	Do. . .	Q. L. .	24	29th July 1932	Do.
Do. .	(283) Mr. Shamjee Gangjee, Raigarh.	Do. . .	Q. L. .	5	28th August 1933.	Do.

P. L.=*Prospecting License.* M. L.=*Mining Lease.* Q. L.=*Quarry Lease.*

CENTRAL PROVINCES—*contd.*

District.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Bilaspur .	(284) Messrs. Guruduttanus Kashiram.	Limestone . .	Q. L. .	2	18th February 1933.	10 years.
Do.	(285) Mr. Jairam Valjee, Contractor of Raigarh.	Do . .	Q. L. .	43	19th April 1932.	Do.
Do. .	(286) Mr. Ranchhorlal, Brahman of Bilaspur.	Clay . . .	Q. L. .	2	8th February 1933.	5 years.
Do. .	(287) Mr. Deoman, Son of Narhar, Kannojia Chamber, Juna Bilaspur.	Do. . . .	Q. L. .	1	31st March 1933.	Do.
Do. .	(288) Mr. Tulsiram, Mahar of Magarpara, Bilaspur.	Do. . . .	Q. L. .	8	29th July 1933	2 years.
Do. .	(289) Mr. Mukutram of Magarpara, Bilaspur.	Do. . . .	Q. L. .	1	7th June 1933	Do.
Do. .	(290) Mr. Ganpat Rao Vinayak Rao Sheah, Juna Bilaspur.	Do. . . .	Q. L. .	1	30th March 1933.	Do.
Do. .	(291) Mr. Muljee Jagmal, Bengal Nagpur Ry. Contractor, Bilaspur.	Do. . . .	Q. L. .	2	11th February	5 years.
Do. .	(292) Do. .	Do. . . .	Q. L. .	2	1st September 1933.	3 years.
Do. .	(293) Messrs. Dunlop and Considine, Gherdewa Coal Fields, Ltd.	Coal . . .	P. L. .	10,297	8th April 1933.	1 year.
Chhindwara.	(294) Seth Bansidhar Ramniwas Goenka of Nagpur.	Do. . . .	M. L. .	828	7th July 1933	30 years.
Do. .	(295) Mr. D. Nargolwala of Nagpur.	Do. . . .	P. L. .	278	18th February 1933.	1 yea
Do. .	(296) Do. .	Do. . . .	P. L. .	516	20th March 1933.	Do.
Do. .	(297) Haji Syed Zahiruddin of Chhindwara.	Do. . . .	P. L. .	376	22nd March 1933.	Do.
Do. .	(298) Do. .	Do. . . .	P. L. .	183	18th May 1933.	Do.
Do. .	(299) Seth Bansidhar Ramniwas Goenka of Nagpur.	Do. . . .	P. L. .	267	17th July 1933.	Do.
Do. .	(300) Messrs. Mangal Singh Ishwar Singh of Nagpur.	Do. . . .	P. L. .	198	16th August 1933.	Do.
Do. .	(301) Mr. Syed Jamal of Junnardeo.	Do. . . .	P. L. .	492	7th September 1933.	Do.
Do. .	(302) Messrs. Jagannath Ramdayal of Cawnpore.	Do. . . .	P. L. .	1,146	22nd September 1933.	Do.

P. L.=*Prospecting License.* M. L.=*Mining Lease.* Q. L.=*Quarry Lease.*

CENTRAL PROVINCES—*contd.*

District.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Chhindwara.	(303) Seth Bansidhar Ramniwas Goenka of Nagpur.	Coal . . .	P. L. .	316	25th September 1933.	1 year.
Do. .	(304) Do. .	Do. . . .	P. L. .	200	Do. .	Do.
Do. .	(305) Do. .	Do. . . .	P. L. .	142	Do. .	Do.
Do. .	(306) Messrs. Mangal Singh Iswar Singh of Nagpur.	Do. . . .	P. L. .	557	12th October 1933.	Do.
Do. .	(307) Messrs. Walji Bhimji and Sons of Junnerdeo.	Do. . . .	P. L. .	495	16th November 1933.	Do.
Do. .	(308) Seth Bansidhar Ramniwas Goenka, Nagpur.	Do. . . .	P. L. .	270	20th November 1933.	Do.
Do. .	(309) Mr. Syed Jamal of Junnardeo.	Do. . . .	P. L. .	617	22nd November 1933.	Do.
Do. .	(310) Messrs. Pench Valley Coal Company, Ltd., Parasia.	Do. . . .	P. L. .	62	2nd December 1933.	Do.
Do. .	(311) Messrs. Mangal Singh Ishwar Singh of Nagpur.	Do. . . .	P. L. .	302	Do. .	Do.
Do. .	(312) Seth Hazarimal Bazaz of Chhindwara.	Do. . . .	P. L. .	66	Do. .	Do.
Jubbulpore.	(313) The C. P. Cement Company, Limited, Bombay.	Limestone . .	Q. L. .	10	8th April 1933	16th years.
Do. .	(314) Do. .	Do. . .	P. L. .	814	5th January 1933.	1 year.
Do. .	(315) The C. P. Portland Cement Co., Ltd., Katni.	Do. . .	P. L. .	277	Do. .	Do.
Do. .	(316) Mr. Nasharwanji Manackji Dubash.	Do. . .	Q. L. .	1	24th May 1933.	10 years.
Do. .	(317) Mr. T. C. Dunne	Do. . .	Q. L. .	6	27th January 1933.	Do.
Do. .	(318) Mr. Nasharwanji Manackji Dubash.	Do. . .	Q. L. .	9	8th May 1933	Do.
Do. .	(319) The Imperial Stone Lime Manufacturing Co., Maihar.	Do. . .	P. L. .	116	5th January 1933.	1 year.
Do. .	(320) Messrs. Bansaroop Balbhadar Pandey of Katni.	Do. . .	Q. L. .	3	27th October 1933.	10 years.
Do. .	(321) Seth Gangadhar Rameshardas, Katni.	Red and yellow ochre	P. L. .	53	26th April 1933.	1 year.
Do. .	(322) The Imperial Stone Lime Manufacturing Co., Maihar.	Limestone . .	P. L. .	100	25th August 1933.	Do.

P. L.=Prospecting License. Q. L.=Quarry Lease.

CENTRAL PROVINCES—*concld.*

District.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Nagpur	(323) Mr. Shamji Naranji of Ramtek.	Manganese-ore	M. L.	58	14th December 1932.	10 years.
Do.	(324) Mr. M. A. Razaq, Kamptee.	Do.	M. L.	80	18th February 1933.	Do.
Raipur	(325) Mr. Ganpat Rao Laxman Rao of Nagpur.	Flag stone	Q. L.	9	28th October 1933.	Do.
Do.	(326) Mr. Rikhiram Contractor of Raipur.	Clay	Q. L.	16	10th December 1932.	Do.
Yeotmal	(327) Rai Bahadur Bansilal Abirchand, Kamptee.	Coal	P. L.	2,764	24th October 1933.	1 year.
Do.	(328) Messrs. Wasudeorao and Brothers, Nagpur.	Limestone	P. L.	116	1st August 1933.	Do.
Do.	(329) Mrs. Ganpat Rao Laxman Rao, Nagpur.	Do.	P. L.	51	12th October 1933.	Do.
Do.	(330) Mr. M. D'Costa, Nagpur.	Do.	P. L.	12	14th September 1933.	Do.
Do.	(331) Do.	Do.	P. L.	23	25th November 1933.	Do.
Do.	(332) Mr. Ganpat Rao Laxman Rao, Nagpur.	Do.	P. L.	49	29th November 1933.	Do.
Do.	(333) Messrs. Wasudeorao and Brothers, Nagpur.	Do.	P. L.	52	12th October 1933.	Do.
Do.	(334) Do.	Do.	Q. L.	6	28th October 1933.	10 years.

MADRAS.

District.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Anantapur	(335) Mr. Vegarazu Venkatasubbayya.	Barytes	P. L.	60·00	27th April 1933.	1 year.
Do.	(336) Mr. Dasaratharama Reddi.	Do.	P. L.	63·00	1st November 1933.	Do.
Chingleput	(337) Messrs. Parry & Co., Madras.	Blue clay	M. L.	0·24	1st April 1933	10 years.
Chittoor	(338) Mr. T. Audimula Mudaliyar, Sholingur.	Mica	M. L.	226·00	1st July 1933	30 years.
Cuddapah	(339) Mr. S. S. Guzdar of Calcutta.	Barytes	M. L.	74·80	Do.	Do.
Do.	(340) Do.	Do.	P. L.	84·80	22nd June 1933	1 year.
Do.	(341) Mr. K. Abdul Hye Sahib of Bellary.	Do.	P. L.	5·42	20th December 1932.	Do.

P. L.=*Prospecting License.* M. L.=*Mining Lease.* Q. L.=*Quarry Lease.*

MADRAS—*contd.*

District.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Cuddapah .	(342) Mr. K. Abdul Hye Sahib of Bellary.	Barytes . . .	P. L. .	7·90	1st June 1933	1 year.
Do. .	(343) Mr. S. S. Guzdar of Calcutta.	Do. . .	P. L. .	9·90	10th December 1932.	Do.
Do. .	(344) Do. .	Do. . . .	P. L. .	172·96	30th November 1933.	Do.
Do. .	(345) Do. .	Asbestos . .	P. L. .	56·23	3rd June 1933	Do.
Do. .	(346) Mr. K. Balakrishna Nayudu of Madras.	Aluminium silicate .	P. L. .	4·00	14th September 1933.	Do.
Do. .	(347) Mr. S. S. Guzdar of Calcutta.	Barytes . . .	P. L. .	8·73	11th November 1933.	Do.
Do. .	(348) Do. .	Do. . . .	P. L. .	4·80	23rd August 1933.	Do.
Do. .	(349) Mr. Dasaratharama Reddi of Madras.	Do. . . .	P. L. .	63·87	8th November 1933.	Do.
Guntur .	(350) Mr. Manji Bechar of Purulia (Bengal-Nagpur Railway).	Lead, barytes, steatite and magnesite.	P. L.	398·00	18th December 1933.	Do.
Kurnool .	(351) Mr. Ashruff Hussain Khan Mandozie.	Barytes . . .	M. L. .	22·00	27th September 1933.	5 years.
Do. .	(352) Do. .	Do. . . .	M. L. .	13·29	Do. .	Do.
Do. .	(353) Mr. Bepari Abdul Nabi Sahib.	Do. . . .	M. L. .	10·92	6th October 1933.	Do.
Do. .	(354) Mr. Ashruff Hussain Khan Mandozie.	Do. . . .	P. L. .	30·00	5th April 1933	1 year.
Do. .	(355) Messrs. Narayandas Girdhardas and C. Manavalan.	Do. . . .	P. L. .	206·00	5th June 1933	Do.
Do. .	(356) Do. .	Lead-ore. . .	P. L. .	16·93	23rd June 1933.	Do.
Do. .	(357) Mr. Manji Bechar	Barytes . . .	P. L. .	7·83	31st July 1933	Do.
Do. .	(358) Do. .	Do. . . .	P. L. .	29·62	31st August 1933.	Do.
Do. .	(359) Do. .	Do. . . .	P. L. .	16·01	Do. .	Do.
Do. .	(360) Do. .	Do. . . .	P. L. .	0·45	6th September 1933.	Do.
Do. .	(361) Do. .	Do. . . .	P. L. .	5·50	31st August 1933.	Do.
Do. .	(362) Mr. B. Venkataswami Chetti.	Red oxide of iron .	P. L. .	20·00	26th August 1933.	Do.
Do. .	(363) Do. .	Lead, zinc and barytes.	P. L. .	16·00	9th August 1933.	Do.
Do. .	(364) Do. .	China clay or kaolin	P. L. .	6·00	26th August 1933.	Do.

P. L.=Prospecting License. *M. L.=Mining Lease.*

MADRAS—*contd.*

District.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Kurnool .	(365) Mr. B. Venkataswami Chetti.	China clay or kaolin	P. L. .	2·00	17th August 1933.	1 year.
Do. .	(366) Do. .	Barytes	P. L. .	87·20	18th August 1933.	Do.
Do. .	(367) Do. .	Do.	P. L. .	30·33	16th September 1933.	Do.
Do. .	(368) Mr. Manji Bechar	Do.	P. L. .	25·93	Do. .	Do.
Do. .	(369) Mr. Bepari Abdul Nabi Sahib.	Do.	P. L. .	42·00	17th October 1933.	Do.
Do. .	(370) Do. .	Do.	P. L. .	59·00	Do. .	Do.
Do. .	(371) Mr. Madasu Pedda Rangappa.	Do.	P. L. .	26·00	9th November 1933.	Do.
Do. .	(372) Mr. Manji . .	Do.	P. L. .	38·54	1st November 1933.	Do.
Do. .	(373) Mr. R. F. Nariman.	Do.	P. L. .	21·00	3rd October 1933.	Do.
Do. .	(374) Messrs. Narayandas Girdhardas and C. Manavalan.	China clay or kaolin .	P. L. .	16·50	31st August 1933.	Do.
Do. .	(375) Mr. Ashraff Hussain Khan Mandozie	Barytes	P. L. .	23·07	29th June 1933.	Do.
Do. .	(376) Mr. S. S. Guzdar	Bartyes and yellow ochre.	P. L. .	19·00	1st December 1933.	Do.
Do. .	(377) Do. .	Barytes	P. L. .	136·00	17th November 1933.	Do.
Do. .	(378) Do. .	Do.	P. L. .	46·00	Do. .	Do.
Do. .	(379) Messrs. Narayanadas Girdhardas and C. Manavalan.	Do.	P. L. .	59·00	6th October 1933 .	Do.
Do. .	(380) Mr. Madasur Pedda Rangappa.	Do.	P. L. .	2·87	1st December 1933.	Do.
Do. .	(381) Do. .	Do.	P. L. .	7·00	Do. .	Do.
Do. .	(382) M. B. Venkataswami Chetti.	Lead-ore and zinc .	P. L. .	0·60	4th December 1933.	Do.
Do. .	(383) Messrs. Narayanadas Girdhardas and C. Manavalan.	Silver, lead, zinc and other minerals.	P. L. .	21·00	8th December 1933.	Do.
Do. .	(384) Mr. B. P. Sesha Reddi.	Steatite	P. L. .	27·50	24th December 1933.	Do.
Nellore .	(385) Mr. C. M. Garudachar.	Mica	P. L. .	8·43	24th April 1933.	Do.
Do. .	(386) Messrs. Vemi Reddi and Adisesha Reddi.	Do.	M. L. .	48·69	20th August 1933.	30 years.

P. L. = *Prospecting License.* M. L. = *Mining Lease.*

MADRAS—*concld.*

District.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Nellore .	(387) Mr. P. Venkayya	Mica . . .	P. L. .	246·84	30th May 1933.	1 year.
Do. .	(388) Mr. V. G. Krishna Rao.	China clay . .	P. L. .	6·09	20th October 1933.	Do.
Do. .	(389) Mr. P. Venkayya	Mica . . .	P. L. .	15·22	10th August 1933.	Do.
Tinnevelly .	(390) Mr. Annavi Harikrishna Nadar.	Garnet sand . .	M. L. .	1·57	11th January 1933.	3 years.

NORTH-WEST FRONTIER PROVINCE.

District.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Bannu .	(391) The Indo-Burma Petroleum Co., Ltd.	Natural petroleum (including natural gas).	P. L. . (Renewal).	5,913·6	3rd February 1933.	1 year.
Do. .	(392) Do. .	Do. .	P. L. . (Renewal).	3,040·0	3rd August 1933.	Do.
Do. .	(393) The Burmah Oil Co., Ltd.	Do. .	P. L. . (Renewal).	11,744·0	2nd September 1933.	Do.
Dera Ismail Khan.	(394) The Indo-Burma Petroleum Co., Ltd.	Mineral oil . .	P. L. . (Renewal).	2,995·2	10th September 1933.	Do.
Do. .	(395) The Attock Oil Co., Ltd.	Do. . .	P. L. . (Renewal).	150·0	26th November 1933.	Do.
Do. .	(396) The Burmah Oil Co., Ltd.	Natural petroleum (including natural gas).	P. L. . (Renewal).	1,504·0	2nd September 1933.	Do.

PUNJAB.

District.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Jhelum .	(397) Pandit Gian Chand and Lala Ram Lal, Dandot.	Coal . . .	P. L. .	66	9th December 1933.	1 year.
Do. .	(398) Lala Ram Lal of Wahula, Dandot.	Do. . . .	P. L. .	125	1st July 1933	Do.
Do. .	(399) Lala Sant Ram Kapur, Pind Dadan Khan.	Do. . . .	P. L. .	280	21st August 1933.	Do.
Do. .	(400) The Chakwal Brick Company, Chakwal.	Do. . . .	P. L. .	93	1st April 1933	Do.
Do. .	(401) The Lahore Industries Ltd.	Do. . . .	M. L. .	103	1st May 1933	30 years.
Do. .	(402) Bhai Hazura Mal, Dandot.	Do. . . .	M. L. .	115	30th September 1933.	Do.
Do. .	(403) Lala Ram Lal Chanda of Tatral Tehsil, Pind Dadan Khan.	Do. . . .	P. L. .	88	8th July 1933	1 year.

P. L.=*Prospecting License.* M. L.=*Mining Lease.*

PUNJAB—*contd.*

District.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Jhelum .	(404) Bhai Hazura Mal, Dandot.	Coal . . .	M. L. .	61	13th October 1933.	30 years.
Mianwali .	(405) Lala Ishar Das Kapur, Pind Dadan Khan.	Do. . . .	M. L. .	800	14th June 1933.	Do.

UNITED PROVINCES.

Almora .	(406) Mr. Prag Narain, Rawatpara, Agra.	Copper and allied minerals.	P. L. .	640	9th December 1933.	1 year.

P. L.=*Prospecting License.* M. L.=*Mining Lease.*

SUMMARY.

Province.	Prospecting Licenses.	Mining Leases.	Quarry Leases.	Total of each Province.
Ajmer-Merwara	8	3	..	11
Assam	13	..	..	13
Baluchistan	2	4	..	6
Bihar and Orissa	2	15	..	17
Bombay	2	..	..	2
Burma	203	12	..	215
Central Provinces	35	11	24	70
Madras	48	8	..	56
North-West Frontier Province	6	..	..	6
Punjab	5	4	..	9
United Provinces	1	..	..	1
Total of each kind and grand total .	325	57	24	406
Total for 1932 .	249	52	26	327

CLASSIFICATION OF LICENCES AND LEASES.

TABLE 49.—*Prospecting Licenses and Mining Leases granted in Ajmer-Merwara during the year 1933.*

District.	1933.		
	No.	Area in acres.	Mineral.
	PROSPECTING LICENSES.		
Ajmer	2	11·7	Mica.
Do.	1	20·0	Beryl, folspar and quartz.
Do.	1	0·8	Felspar, China clay and mica.
Do.	2	4·2	Mica and beryl.
Do.	1	1·7	Beryl and folspar.
Beawar . . .	1	6·6	Mica.
TOTAL .	8		
	MINING LEASES.		
Ajmer	3	37·6	Mica.

TABLE 50.—*Prospecting Licenses granted in Assam during the year 1933.*

District.	1933.		
	No.	Area in acres.	Mineral.
Cachar	4	11,399·4	Mineral oil.
Lakhimpur . . .	6	18,152·3	Petroleum.
Sylhet	3	15,303·2	Mineral oil.
TOTAL .	13		

TABLE 51.—*Prospecting Licenses and Mining Leases granted in Baluchistan during the year 1933.*

DISTRICT.	1933.		
	No.	Area in acres.	Mineral.
	PROSPECTING LICENSES.		
Kalat	2	2,720	Coal.
	MINING LEASES.		
Kalat	3	330	Coal.
Quetta-Pishin	1	150	Do.
TOTAL	4		

TABLE 52.—*Prospecting Licenses and Mining Leases granted in Bihar and Orissa during the year 1933.*

DISTRICT.	1933.		
	No.	Area in acres.	Mineral.
	PROSPECTING LICENSES.		
Hazaribagh	1	51·2	Sillimanite, kyanite and abrasive garnet.
Singhbhum	1	204·8	Chromite.
TOTAL	2		
	MINING LEASES.		
Santal Parganas	15	43·9	Coal.

TABLE 53.—*Prospecting Licenses granted in the Bombay Presidency during the year 1933.*

DISTRICT.	1933.		
	No.	Area in acres.	Mineral.
Belgaum	1	558	Bauxite.
Ratnagiri	1	1,280	Chromite.
TOTAL	2		

TABLE 54.—*Prospecting Licenses and Mining Leases granted in Burma during the year 1933.*

District.	1933. No.	1933. Area in acres.	1933. Mineral.
	PROSPECTING LICENSES.		
Akyab	3	11,776·0	Natural petroleum (including natural gas).
Amherst	4	3,520·0	All minerals except oil.
Lower Chindwin	1	3,187·2	Natural petroleum (including natural gas).
Magwe	5	18,300·4	Ditto.
Mergui	41	13,984·4	Tin and allied minerals.
Do.	3	1,542·4	All minerals except oil.
Do.	6	1,721·6	Tin and wolfram.
Do.	36	14,662·4	Tin-ore.
Do.	4	947·2	Tin and other minerals.
Do.	1	377·6	All minerals.
Do.	3	1,391·4	Tin, wolfram and allied minerals.
Do.	1	748·8	Wolfram and allied minerals.
Do.	2	928·0	Tin and all minerals except coal and oil.
Do.	1	390·4	Gold, tin and allied minerals.
Minbu	1	1,280·0	Natural petroleum (including natural gas), coal and other minerals.
Do.	1	80·0	Natural petroleum (including natural gas).
Myingyan	2	1,920·0	Ditto.
Myitkyina	3	4,800·0	Gold and platinum.
Northern Shan States	1	1,680·0	Lead and silver.
Ditto	10	10,137·6	All minerals.
Pakokku	3	586·4	Natural petroleum (including natural gas).
Salween	1	640·0	All minerals except mineral oil.
Southern Shan States	1	640·0	Wolfram.
Ditto	6	12,665·6	All minerals except mineral oil.
Thaton	4	2,688·0	Ditto.
Thayetmyo	5	6,803·2	Natural petroleum (including natural gas).
Tavoy	24	11,958·4	Tin and wolfram.
Do.	4	1,081·6	Tin and allied minerals.
Do.	14	9,416·3	All minerals except oil.
Upper Chindwin	3	11,840·0	Natural petroleum (including natural gas).
Do.	2	1,265·2	Coal.
Yamethin	1	640·0	Wolfram and mixed ores.
Do.	2	1,580·8	All minerals except oil and precious stones.
Do.	4	2,560·0	All minerals except mineral oil.
TOTAL	203		

TABLE 54.—*Prospecting Licenses and Mining Leases granted in Burma during the year 1933*—contd.

DISTRICT.	1933.		
	No.	Area in acres.	Mineral.
	MINING LEASES.		
Magwe	1	1,280·0	Natural petroleum (including natural gas).
Mergui	2	492·8	Tin and allied minerals.
Do.	1	70·4	Tin-ore.
Northern Shan States .	1	320·0	Lead, silver, zinc and copper.
Ditto . .	1	37·7	Iron-ore.
Thayetmyo	1	320·0	Natural petroleum (including natural gas.)
Tavoy	1	96·0	Wolfram ore.
Do.	2	236·8	Tin-ore.
Do.	2	185·6	Tin and wolfram.
TOTAL .	12		

TABLE 55.—*Prospecting Licenses and Mining and Quarry Leases granted in the Central Provinces during the year 1933.*

DISTRICT.	1933.		
	No.	Area in acres.	Mineral.
	PROSPECTING LICENSES.		
Balaghat	1	388	Manganese-ore.
Bhandara	2	103	Corundum and kyanite.
Do.	1	47	China clay.
Bilaspur	1	10,297	Coal.
Chhindwara	18	6,483	Do.
Jubbulpore	4	1,307	Limestone.
Do.	1	53	Red and yellow ochre.
Yeotmal	1	2,764	Coal.
Do.	6	303	Limestone.
TOTAL .	35	..	
	MINING LEASES.		
Balaghat	6	2,107	Manganese-ore.
Bhandara	2	469	Do.
Chhindwara	1	828	Coal.
Nagpur	2	138	Manganese-ore.
TOTAL .	11	..	

TABLE 55.—*Prospecting Licenses and Mining and Quarry Leases granted in the Central Provinces during the year 1933*—contd.

District.	1933. No.	1933. Area in acres.	1933. Mineral.
	QUARRY LEASES.		
Bhandara	1	45	Sand.
Do.	1	7	Clay.
Do.	1	4	Flooring stone.
Do.	1	1	Clay and sand.
Bilaspur	5	92	Limestone.
Do.	7	12	Clay.
Jubbulpore	5	29	Limestone.
Raipur	1	9	Flag stone.
Do.	1	16	Clay.
Yeotmal	1	6	Limestone.
TOTAL	24		

TABLE 56.—*Prospecting Licenses and Mining Leases granted in the Madras Presidency during the year 1933.*

DISTRICT.	1933. No.	1933. Area in acres.	1933. Mineral.
	PROSPECTING LICENSES.		
Anantapur	2	123·00	Barytes.
Cuddapah	8	358·38	Do.
Do.	1	56·23	Asbestos.
Do.	1	4·00	Aluminium silicate.
Guntur	1	398·00	Lead, barytes, steatite, and magnesite.
Kurnool	1	0·60	Lead-ore and zinc.
Do.	1	21·00	Silver, lead, zinc and other minerals.
Do.	1	16·93	Lead-ore.
Do.	1	20·00	Red oxide of iron.
Do.	1	27·50	Steatite.
Do.	1	16·00	Lead, zinc and barytes.
Do.	1	19·00	Barytes and yellow ochre.
Do.	3	24·50	China clay or kaolin.
Do.	21	784·48	Barytes.
Nellore	3	270·49	Mica.
Do.	1	6·00	China clay.
TOTAL	48		

TABLE 56.—*Prospecting Licenses and Mining Leases granted in the Madras Presidency during the year 1933*—contd.

District.	1933.		
	No.	Area in acres.	Mineral.
	MINING LEASES.		
Chingleput . . .	1	0·24	Clay.
Chittoor . . .	1	226·00	Mica.
Cuddapah . . .	1	74·80	Barytes.
Kurnool . . .	3	46·21	Do.
Nellore	1	48·69	Mica.
Tinnevelly . . .	1	1·57	Garnet sand.
TOTAL .	8		

TABLE 57.—*Prospecting Licenses granted in the North-West Frontie Province during the year 1933.*

DISTRICT.	1933.		
	No.	Area in acres.	Mineral.
Bannu	3	20,697·0	Natural petroleum (includin natural gas).
Dera Ismail Khan . .	2	3,145·2	Mineral oil.
Do. . .	1	1,504·0	Natural petrole (includin natural gas).
TOTAL .	6		

TABLE 58.—*Prospecting Licenses and Mining Leases granted in the Punjab during the year 1933.*

DISTRICT.	1933.		
	No.	Area in acres.	Mineral.
	PROSPECTING LICENSES.		
Jhelum	5	652	Coal.
	MINING LEASES.		
Jhelum	3	269	Coal.
Mianwali . . .	1	360	Do.
TOTAL .	4		

TABLE 59.—*Prospecting License granted in the United Provinces during the year 1933.*

DISTRICT.	1933.		
	No.	Area in acres.	Mineral.
Almora	1	640	Copper and allied minerals.

NOTE ON THE MANGANESE-LIME SERIES OF GARNETS. BY L. L. FERMOR, O.B.E., D.Sc., A.R.S.M., F.R.S., F.A.S.B., *Director, Geological Survey of India.* (With Plate 22.)

In a paper published in 1926[1], I wrote 'On the Composition of some Indian Garnets', making use of some nine analyses by Mr. S. N. Godbole of the Victoria College of Science, Nagpur, on material supplied by me, and of such other analyses (eight in number) of Indian garnets as were available. In addition to the presence of five out of the six standard garnet molecules, it was shown that the interpretation of some of the analyses indicated the presence of other garnet molecules of which three were detected and named as follows :—

$3\,FeO.Fe_2O_3.3SiO_2$	Skiagite.
$3\,MnO.Fe_2O_3.3SiO_2$	Calderite.
$3\,MnO.Mn_2O_3.3SiO_2$	Blythite.

As very few natural garnets contain a high enough percentage of one molecule to be designated by the name of that molecule alone, compound names were suggested to allow for any molecule present to the extent of 20 per cent. or over. The possibility of using formulae was also illustrated by examples, after allotting a formula to each garnet molecule, such as Py for pyrope, and Sp for spessartite. A diagram was also given (*l. c.*, Plate 10) illustrating the composition of the 17 Indian garnets and showing all the eight garnet molecules.

Recently a paper has been published by Messrs. M. B. Ramachandra Rao and K. Sripada Rao 'On the origin and correlation of the metamorphic rocks of the Sakarsanhalli area, Kolar district'[2]. This paper is of interest because it contains a geological map of an area of some importance in the correlation of the Dharwar rocks,[3] as well as a discussion of the origin and relationships of the rocks that were once called by Mr. Jayaram[4] the Sakarsanite series, a

[1] *Rec. Geol. Surv. Ind.*, LIX, pp. 191-207.
[2] *Bull. Mys. Geol. Dept.*, No. 14, pp. 1-33, (1934).
[3] *Rec. Geol. Surv. Ind.*, LIII, pp. 22-23, (1921); and LIX, p. 92, (1926).
[4] *Rec. Mys. Geol. Dept.*, III, pp. 169-171, (1903) and XXII, pt. 2, pp. 29-35, [1925].

name which would be better transformed into Sakrasanhalli series, after the village near which they occur.

The authors conclude (*l. c.*, p. 15) that the rocks of the Sakrasanhalli series (they do not use this name) are Dharwar in age, and that, with the associated hornblende-schists, they must at one time have formed 'a more or less continuous series with the Kolar schist belt but are now much torn up, isolated and severely disturbed by the later intrusive gneissic granites'. This conclusion seems justified by the facts.

In addition the authors express the view that the pyroxenic (diopsidic) rocks designated tarurites and associated rocks containing manganese-garnet and rhodonite, as well as the associated limestones —in part black manganiferous ones like those of Devi [1] and other places in the Central Provinces—are all derivatives by metamorphic alteration of original igneous hornblende-schists. This is a question upon which more than one opinion is possible on the facts; it is not, however, intended to discuss this question here, but only the analysis of a manganese-garnet from Sakrasanhalli that is given in the paper and conclusions to be drawn therefrom. The authors give the analysis of this garnet and then state that (*l.c.*, p. 28)

'A comparison with the list of analyses and calculations of the nine specimens of garnets from different Indian localities furnished by Dr. Fermor shows that it does not correspond to any of them; but a comparison with the analyses of garnets furnished by Dana shows that it comes very near to a Spessartite from Ilmen Mts. .... excepting for a much higher percentage of CaO in our specimen.'

To neglect to take account of the comparatively high CaO contents of the Sakrasanhalli garnet impairs the argument of the authors, for if this constituent be taken into account it is seen quickly that the Sakrasanhalli garnet is closely related in composition to certain of the garnets represented by the nine analyses mentioned, and in fact forms in composition a member of the manganese-lime-series of garnets of which the spessartite of the gondite series occupy the high MnO end and the spanditic garnets of the kodurite series the high CaO end. On the other hand, the garnet from the Ilmen Mts., in spite of its high MnO contents, is more closely related to the almanditic garnets characteristic of argillaceous schists and pegmatites intrusive therein.

[1] *Rec. Geol. Surv. Ind.*, XXXIII, pp. 200, 201, Plate 17, fig. 1, (1906).

As the view that the Sakrasanhalli garnet is more like the garnet from the Ilmen Mts. then any of the garnets represented in my set of nine analyses has been taken implicitly as an argument against the possibility of any of the rocks of the Sakrasanhalli series being related to the gonditic and other rocks of presumed sedimentary origin in the Sausar series of the Central Provinces, to establish the reverse must be regarded as an argument in favour of the possibility that the manganiferous rocks of Sakrasanhalli *are* related to the gonditic rocks of the Central Provinces.

In Table No. 1 are shown twelve analyses of garnets, nine of them being garnets from the gondite and kodurite series given in Tables 1 and 5 of my 1926 paper, two of them being the Sakrasanhalli and Ilmen Mts. analyses referred to above, and the twelfth, an analysis of a garnet from a pegmatite at Biradavole in the Nellore district, also taken from the same paper. With one exception the analyses are arranged in order of MnO contents, which brings the Ilmen Mts. analysis next to that of the Sakrasanhalli garnet.

On scanning these analyses it is seen at once that ten of the analyses belong to a series in which, on the whole, decreasing MnO contents is accompanied by increasing CaO contents. But there are two strangers to the series. One is the garnet from the Ilmen Mts. and the other is that from Biradavole, which has been purposely placed last, because it is known to be a stranger to the MnO-CaO series of garnets. The Sakrasanhalli garnet, on the other hand, is obviously closest in composition to the garnet from Kotakarra, which, but for the interposition of the garnet from the Ilmen Mts., would be next to it.

The relationships of these garnets are, however, still better understood if the analyses are recalculated in terms of garnet molecules, as is done in Table No. 2, where impurities are rejected and the garnet molecules calculated to a total of 100 per cent.[1]

The relationship of the Sakrasanhalli garnet to the gondite-kodurite series of garnets can also be illustrated by a diagram. In the diagram forming Plate 10 of my 1926 paper the Sakrasanhalli garnet falls naturally between the ninth and tenth garnet from the left, whilst the garnet from the Ilmen Mts. falls immediately to the right of the fifth garnet from the left (the Nellore garnet).

[1] The Ilmen Mts. analysis suffers from the defect that it only yields some 80 per cent. of garnet, the whole of the Fe_2O_3 being surplus, as well as a portion of the silica and alumina. By treating the Fe_2O_3 as FeO the total garnet comes to nearly 93·93 per cent. with a surplus of 2·24 per cent. SiO_2, 1·99 per cent. Al_2O_3 and 0·65 per cent. oxygen.

TABLE 1.—*Results of analysis of 11 Indian garnets and one foreign.*

No. in Plate 22	Specimen No.	Locality.	Sp. gr.	SiO_2	Al_2O_3	Fe_2O_3	FeO	MnO	MgO	CaO	Loss etc.	Total.	Total Fe	Total Mn	Total Fe & Mn	Name.	Rock in which found.
1	18/871 (1060)	Chargaon, Nagpur	4·15-4·2	34·71	8·05	8·38	n. d.	38·38	5·40	4·77	tr.	100·34	5·86	30·07	35·93	Magnesia-blythite	Gondite series.
2	18/912 .	Satak, Nagpur .	4·13	34·73	22·46	4·51	1·63	35·30	..	0·97	..	99·60	4·42	27·26	31·78	Spessartite . .	Do.
3	18/582 .	Nautan Barampur, Ganjam.	..	38·61	17·91	8·75	3·02	26·51	2·18	1·95	..	98·93	8·47	20·53	29·00	Spessartite . .	Apatite-spessartite-rock.
4	17/63 .	Bichua, Chhindwara.	3·95 (4·02)	36·02	19·79	5·93	5·98	26·06	1·35	5·06	..	100·19	8·80	20·18	28·98	Spessartite . .	Pegmatite in gondite.
5	16/984 .	Wagora, Chhindwara.	4·24	37·73	21·26	..	9·94	24·48	3·48	3·11	..	100·00	7·73	18·95	26·68	Ferro-spessartite .	Gondite.
6	R_2/989 .	Sakrasanhalli, Mysore.	4·10	39·05	19·92	2·07	6·01	21·69	1·23	11·26	..	101·23	6·12	16·52	22·94	Calc-spessartite .	Sakrasanhalli series.
7		*Ilmen Mts.* (*Dana*).	..	*36·60*	*21·46*	*6·48*	*10·90*	*20·86*	*0·24*	*2·27*	*0·28*	*99·09*	*13·2*	*16·16*	*29·18*	*Spalmandite* .	?
8	18/398 (A-238).	Kotakarra, Vizagapatam.	..	37·57	18·98	3·47	7·45	16·50	0·23	15·80	..	100·00	8·22	12·77	20·99	Calc-spessartite .	Opalised kodurite.
9	18/378 (A-219).	Garbham, Vizagapatam.	4·02	35·24	6·48	23·90	n. d.	16·37	2·04	15·29	0·18 (Ba O)	99·41	16·73	12·68	29·41	Spandite . .	Spandite-rock.
10	18/482 (233)	Kodur, Vizagapatam.	3·72	32·76	7·92	18·54	1·23	11·77	0·69	24·43	..	97·34	13·94	9·12	23·06	Spandite . .	Do.
11	18/557 (A-134).	Boirani, Ganjam .	3·76	38·18	14·22	11·41	2·16	2·68	0·65	30·70	..	100·00	9·67	2·07	11·74	Grandite . .	Opalised kodurite.
12	19/546 .	Biradavole, Nellore	4·15	34·81	22·87	14·77	9·38	11·67	..	2·90	..	96·20	17·63	9·04	26·67	Spalmandite.	Pegmatite.

TABLE 2.—*Analyses of 12 garnets according to garnet molecules.*

Number of garnet in Plate.	Registered No. of specimen.	Locality.	Manganese-garnets.			Iron-garnets.		Lime-garnets.		Magnesia-garnets.	
			Spessartite $3 MnO. Al_2O_3. 3 SiO_2$	Calderite. $3 MnO. Fe_2O_3. 3 SiO_2$	Blythite $3 MnO. Mn_2O_3. 3 SiO_2$	Almandite. $3 FeO. Al_2O_3. 3 SiO_2$	Skiagite $3 FeO. Fe_2O_3. 3 SiO_2$	Grossularite. $3 CeG. Al_2O_3. 3 SiO_2$	Andradite. $3 CeO. Fe_2O_3. 3 SiO_2$	Pyrope. $3 MgO. Al_2O_3. 3 SiO_2$	
1	18/871 (1030) .	Chargaon	17·60	12·81	34·72	..	..	..	16·01	18·78	Gondite series.
2	18/912 . .	Satak	86·66	..	..	10·58	..	2·76	..	..	
3	18/582 . .	Nautan-Barampur . .	65·30	..	..	17·31	3·45	..	6·24	7·70	
4	17/63 . .	Bichua	62·78	..	..	18·20	..	11·66	2·69	4·65	
5	16/984 . .	Wagora	57·08	..	..	22·92	..	8·35	..	11·65	
6	R_2/989 . .	Sakrasanhalli . . .	50·82	..	..	13·96	..	25·19	5·80	4·14	Sakrasanhalli series.
7	..	*Ilmen Mts.*	*51·59*	..	..	*41·10*	..	*6·46*	..	*0·80*	
8	18/392 (A-233)	Kotakarra	38·50	..	..	17·24	..	32·43	11·06	0·77	Kodurite series.
9	18/378 (A-219)	Kodur	23·44	17·02	..	..	5·47	..	46·70	6·88	
10	18/482 (233) .	Garbham	30·46	..	..	3·16	..	5·49	58·42	2·56	
11	18/557 (A-134)	Boirani	6·25	..	..	4·99	..	50·13	36·45	2·18	
12	13/546 . .	Biradavole, Nellore . .	31·18	..	..	59·87	..	8·05	..	..	Pegmatite.

I have, however, succeeded in devising another type of diagram that enables four constituents to be represented by points. For this purpose the garnet molecules are collected into four groups according to their RO radicles as shown in table No. 2, and as follows :—

Manganese-garnets—

$3MnO.Al_2O_3.3SiO_2$	Spessartite.
$3MnO.Fe_2O_3.3SiO_2$	Calderite.
$3MnO.Mn_2O_3.3SiO_2$	Blythite.

Iron-garnets—

$3FeO.Al_2O_3.3SiO_2$	Almandite.
$3FeO.Fe_2O_3.3SiO_2$	Skiagite.

Lime-garnets—

$3CaO.Al_2O_3.3SiO_2$	Grossularite.
$3CaO.Fe_2O_3.3SiO_2$	Andradite.

Magnesia-garnets—

$3MgOAl_2O_3.3SiO_2$	Pyrope.

These four groups of garnets are placed at the four corners of a square. Consequently garnets composed wholly of one group would fall at the appropriate corners. Any other garnet composed of mixtures of two or more of these groups can be represented by a point on one of the sides or within the square respectively. Actually none of the garnets studied contains molecules belonging to only one or two of the above groups, so that all the garnets studied fall within the square.

The method adopted for finding the point corresponding to any garnet is to combine the four groups into two adjacent pairs; thus the manganese and iron garnets together and the lime and magnesia garnets together. First a point A is found along the side MF inversely proportional to the ratio of total MnO garnets to total FeO garnets: then another point B is found along the side CP dividing CP in the inverse ratio of CaO garnets to MgO garnets. A and B are then joined by a straight line and this line divided at the point G in the inverse ratio of total MnO *plus* FeO garnets to total CaO *plus* MgO garnets. The point G then represents the composition of the garnet plotted.

It is obvious, however, from inspection of the diagram that the point G can also represent a large number of other mixtures of garnet molecules. Thus the point representing garnet No. 16 in Plate 22 represents also the composition of all the garnets whose ratios of MnO garnets to FeO garnets lie between the points A″ and A′, and

whose ratios of CaO garnets to MgO garnets are represented by corresponding points between P and C. It is obvious, therefore, that for a given point to represent one garnet only the line AB for the particular garnet must be shown in the diagram.

By using this construction the 12 garnets shown in Table 2 of this paper, as also the remaining seven garnets[1] given in Table 7 of my 1926 paper have been represented by points in Plate 22. On the diagram a curved line has been drawn round the nine garnets that belong to either the gondite or the kodurite series. Garnet No. 6 from Sakrasanhalli is seen to fall within this area, whilst garnet No. 7 from the Ilmen Mts. falls well outside.

This diagram thus shows well the relationship of the Sakrasanhalli garnet to the garnets of the gondite and kodurite series.

[1] No. 13=J. 371 from Sarwar.
No. 14=I. 16 from Jaipur.
No. 15=15/181 from Kalahandi.
No. 16=F. 367 from Kulu.
No. 17=M. 1538 from Hazaribagh.
No. 18=Garnet from Hazaribagh.
No. 19=Garnet from Katkamsandi.

EXPLANATION OF PLATE.

PLATE 22.—Diagram illustrating the composition of Indian garnets.

ON THE CHEMICAL COMPOSITION OF THE DECCAN TRAP FLOWS OF LINGA, CHHINDWARA DISTRICT, CENTRAL PROVINCES.

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CONTENTS.

I. INTRODUCTION.

As long ago as 1906, Dr. Fox and I gave an account of the Deccan trap flows of Linga, in the Chhindwara district, Central Provinces.[1] The object of that paper was to describe and discuss the mode of occurrence of these flows in their macroscopic aspect, and we deliberately postponed a discussion of the microscopic and chemical characters of the flows until such time as we should be able to study the large collection of specimens we had made. We considered it then sufficient to refer to the rocks as basalts and dolerites, and to show that the dolerites were integral parts of basaltic lava flows and not intrusive sills. Five flows were identified and mapped separately, and the general succession of characters in these flows from base to surface of a typical flow was outlined, the tendency

[1] *Rec. Geol. Surv. Ind.*, XLVII, pp. 81-136, (1916).

being for the central portions of the flows to be doleritic in texture and the outer portions to be basaltic.[1]

In the years that have since elapsed, other duties have prevented either Dr. Fox or myself from undertaking the microscopic study projected, so that the intended second paper has not been prepared.

In addition to the numerous rock specimens collected during the course of our field work for purposes of microscope study, I collected specially, for purposes of analysis, four specimens representing four out of the five flows studied. Each of these specimens was collected from spots where the rocks appeared to be quite fresh and uniform in texture and appearance.

Recently Prof. A. Lacroix was so good as to offer facilities for the analysis of these specimens by M. Raoult in Paris, and as it seems unlikely that either Dr. Fox or I will be able in the near future to complete a microscopic study of the suite of rocks as a whole it is desirable to publish now these four analyses and a description of the actual rocks analysed.

II. DESCRIPTION OF THE SPECIMENS.

It is convenient first to give an account of the four specimens collected, arranged in ascending order of flows, namely flow 1, flow 2-A, flow 2, flow 3. The distribution of these flows and the localities mentioned below are shown in the map accompanying the paper by Dr. Fox and myself.[2] The microscopic aspect of these four specimens is shown in the photo-micrograph of Plate 23 of the present paper.

Flow 1. Olivine-dolerite. Rock specimen 24/151.
Microscope slide 23356. Locality—Goreyghat.

The specimen was selected from a large heap of fragments of fresh dolerite round the edge of a well sunk into flow 1, the well first piercing soft material representing the vesicular top of this flow overlying the hard dolerite. The well itself was situated about 100 yards east of the Bengal-Nagpur Railway line at a point W. S. W. of Goreyghat village, and had evidently been newly sunk.

In *hand specimen* the rock is dark greyish to brownish black and noticeably crystalline, so that the constituents are discernible with the naked eye, tiny laths of felspar being particularly noticeable, as well as occasional larger resinous felspars.

[1] *Loc. cit.*, p. 99.
[2] *Loc. cit.*, Plate 16.

Under the microscope the rock is seen to be coarse-grained, composed mainly of labradorite felspar laths and prisms, light brownish to brownish grey augite in ophitic to sub-ophitic relationship to the felspar, large black grains of iron-ore often of skeleton shape and enclosing portions of felspar, augite or glass, and a light (to darker) brown completely isotropic glass (darker than the augite) in interstitial relationship to all the principal minerals. The glass is a primary glass and contains long minute colourless needles of apatite, as well as sometimes small augites and occasional felspar laths. This primary glass has been altered in places into greenish yellow to orange-brown palagonite (chlorophaeite) in which the apatite needles are often still preserved; the palagonite varies from isotropic to anisotropic with concentric radiate structures, tending in the latter case to simulate geodic structures. There are also in the fresh glass occasional light green spots of palagonite, which then suggests delessite. The black iron-ore is partly almost equi-dimensional with in places distinct suggestions of hexagonal outlines, and partly in rough bars, the whole being suggestive of ilmenite plates. In one spot in the glass there is a palagonitic patch with associated nearly colourless skeleton prisms of very high refractive index and polarisation recalling sphene and possibly the product of alteration of ilmenite. The rock also contained originally a few rounded olivine phenocrysts, but these have also been largely palagonitised, remnants of the olivine being still visible.

Flow 2A. Basalt (somewhat porphyritic). Rock specimen 24/171. Microscope slide 23357. Locality—Bisapur Khurd.

This specimen was collected from an outcrop in the bed of the Kulbehra river, on the south side, at a point about a quarter of a mile upstream W. N. W. of the village of Bisapur Khurd, and opposite the point where a small tributary joins the north or left bank of the stream. The lava flow as exposed at this point appeared somewhat layered with a tendency to columnar structure and the formation of terraces. The specimen was collected from a columnar portion about one yard high.

In *hand-specimen* this rock is a black fine-grained rock with scattered phenocrysts of felspar of resinous aspect, sometimes in glomero-porphyritic aggregates: minute scattered laths can also be seen.

Under the microscope this rock is seen to be much finer grained than 24/151 (flow 1). There are fairly numerous porphyritic labradorites in a ground-mass composed of laths of plagioclase, granules of augite, and abundant very dark grey-black glass, full of idiomorphic black ores. These ores are partly in skeleton shapes and bars and partly in square crystals, suggesting the presence of both magnetite and ilmenite. The glass contains also minute colourless laths, presumably apatite. There are also numerous patches of green delessitic palagonite, with persistent bars of black ore, the primary glass, felspars and augites having been replaced. These green patches contain laths showing very clearly the emerald green and straw pleochroism of delessite. In a second slide most of the palagonite is chlorophaeitic, the slide being otherwise similar. In the two slides one altered olivine only was detected.

Flow 2. Olivine-dolerite. Rock specimen 24/124.

Microscope slide 23358. Locality—Kulbehra river, east of Dewardha.

In the Kulbehra river east of Dewardha just after the stream has changed in course from an average E. by S. to an average southerly direction, there is a splendid expanse of dolerites of flow 2, showing a rudely columnar structure, with vertical columns jointed into angular blocks bounded by plane, concave, and convex surfaces. At one point the flow is exposed in a cliff 17 feet high, whilst in others it forms two or three terraces. The total thickness of dolerite is about 35 feet. The specimen taken for analysis was broken from a jointed block and is a fresh dark grey dolerite.

In *hand-specimen* this rock is dark greyish black and is distinctly crystalline, though slightly less coarse than 24/151 (flow 1). It is non-porphyritic.

Under the microscope this rock is slightly finer grained than 24/151 (flow 1). It contains the same primary minerals, namely, olivine, labradorite, augite, iron-ore (? ilmenite), and apatite. The augite is not, however, in ophitic or sub-ophitic relationship to the felspar, but is almost corrosive in its relation thereto. The primary glass is grey instead of brown, is less abundant, and tends to be devitrified into units in optic continuity with adjoining felspars, though still retaining clouds of tiny microlites. In consequence the primary glass has not usually given rise to palagonitic alteration products, though in places green (? delessitic) palagonite has been found at the expense of felspar, augite and interstitial glass. The olivines were large and fairly abundant. In one slide they are now represented by large green delessitic pseudomorphs with residual olivine cores, recalling the delessite pseudomorphs of Bhusawal.[1] In a second slide the palagonite is orange-brown, chlorophaeitic, and the olivines are altered to chlorophaeite instead of delessite; the amount of residual olivine is larger. There is also in this second slide a little green palagonite and a delessitic olivine. The rock contains occasional calcite.

Flow 3. Basalt. Rock specimen 42/331.

Microscope slide 23359. Locality—Shikarpur quarry.

On the east bank of the Shikarpur nala where it joins the Kulbehra nala at a point about a quarter of a mile east of the Bengal-Nagpur Railway bridge over the Kulbehra, there is a small hillock with large jointed blocks of trap which had been quarried for the piers of the railway bridge. From this quarry, which is in flow 3, the specimen was collected. The quarry showed pentagonal and hexagonal columns of basalt dipping at 50° to the S. 35° W. The spot from which this specimen was collected is only about half a

[1] *Rec. Geol. Surv. Ind.*, LVIII, p. 122, (1926).

furlong north of the point in the Kulbehra nala at which the specimen of flow 2 was taken. The rock itself is a dark grey compact basalt with felspar phenocrysts.

In *hand-specimen* the rock is dark greyish black, very fine-grained, with occasional small felspar phenocrysts.

Under the microscope this rock differs from the other basaltic specimen, 24/171 (flow 2A), in the comparative absence of felspar phenocrysts and the relatively small amount of primary glass, which is light brownish in tint, with numerous microlites. The iron-ore also is in larger units and is apparently less abundant. The augite is on the whole intersertal. There is a fair amount of green delessitic palagonite formed mainly at the expense of the primary glass. No olivine was detected.

General.

These four rocks are thus seen under the microscope all to contain labradorite felspar (of medium acidity), augite, black-ores, primary glass and apatite needles. In addition the two coarser rocks, the dolerites, contain large olivines partly altered to chlorophaeite or delessite, the character of alteration of the olivine, chlorophaeitic or delessitic, being the same as that of the adjoining palagonite formed at the expense of the primary glass, supporting the view advanced as a result of my study of the lavas of Bhusawal that the only substantial difference between chlorophaeite and delessite lies in the state of oxidation of the iron, ferric for chlorophaeite and ferrous for delessite.[1] Judging from 24/124 (flow 2) the conditions of oxidation vary from ferrous to ferric even within the small distance represented in one thin slice. The presence of palagonite in either its delessitic or chlorophaeitic forms does not, however, mean that the specimens selected for analysis are not fresh. Palagonitisation is a late magmatic change normal to the Deccan trap lavas, and palagonitic products must be regarded as normal constituents of these plateau lavas.

Washington in his well-known account of the Deccan traps[2] classifies his Indian specimens, 17 in number, into four textural types. One of them is said to be holocrystalline, but this term can only have been used in a relative sense, for in my experience holocrystalline forms of the Deccan trap lavas are non-existent, and a careful search will always lead to the discovery of interstitial glass either primary or altered. Commonly even the coarsest dolerites of either

[1] *Rec. Geol. Surv. Ind.*, LVIII, p. 133, (1926).

[2] 'Deccan traps and other plateau basalts,' *Bull. Geol. Soc. Amer.*, Vol. 33, pp. 765-804, (1922).

flows or sills show an abundance of primary glass (*e.g.*, 24/151—flow 1—in the present case).

In none of these 17 rocks does Washington refer to the presence of palagonite or chlorophaeite. It is exceedingly unlikely, however, that such substances were completely absent from all the 17 specimens studied by him, and I am inclined to think that the yellow glass mentioned as present in some of the specimens in Washington's textural type (*b*) must have been chlorophaeite. This seems all the more likely because Washington's specimens showing yellow glass include one from Bhaurameta Hill (26/172), which is within the Linga tract studied by Dr. Fox and myself. This specimen belongs to flow 3 of the present paper, the specimen here described (42/331) containing both primary light brownish glass and delessitic palagonite formed therefrom.

Another point that arises from Washington's paper is the use of the term 'ophitic'. In the account of his type (*a*) the rocks are said (*l.c.*, p. 769) to

'show a typically ophitic texture, the well-twinned labradorite being in sharp tables up to 2 millimeters in length, with anhedral augite intersertal between them.'

This contradiction in the normal use of the terms 'ophitic' and 'intersertal' arises probably from the fact that many Deccan trap dolerites show by ordinary light an apparent ophitic texture under the microscope. When, however, the nicols are crossed, the plates of augite that appear to envelop the felspar laths or prisms resolve themselves into aggregates of augite, and then only occasionally is a felspar crystal seen actually projecting into a single augite plate, as required by the true ophitic structure. When the apparent ophitic structure is thus resolved on crossing the nicols, it is perhaps desirable to call the structure *sub-ophitic*. This is the sense in which I have used this term in describing 24/151 (flow 1). In these flows of Linga described in the present paper, the augite often embays into the felspar as if there has been some corrosion of the felspar during the crystallisation of the augite.

III. CHEMICAL COMPOSITION OF THE SPECIMENS.

For purposes of analysis each selected specimen was broken into two pieces, and one piece set aside for analysis. The specific gravity of this latter piece was then determined and the whole of it ground up for analysis. The powders thus prepared were sent to

Professor Lacroix, who kindly handed them to M. Raoult, by whom the analyses were done. The analyses were thus made on the whole of the material used for the specific gravity determinations. The results are shown in the following table, with the mean of the four analyses, and also the analysis of the specimen of flow 3 given by H. S. Washington :—

Number of flow	Flow 1.	Flow 2A.	Flow 2.	Flow 3.	Mean of the four analyses.	Flow 3.
Number of specimen	24/151.	24/171.	24/124.	42/331.		26/172.
Name of rock	Olivine-dolerite.	Basalt.	Olivine-dolerite.	Basalt.		
Locality	Gorey-ghat.	Bisapur Khurd.	Kulbehra Nala E. of Dewardha.	Shikarpur Quarry.		Bhaura-meta Hill.
Analyst	Raoult.	Raoult.	Raoult.	Raoult.		Washington.
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
SiO_2	49·06	49·20	49·08	49·78	49·28	49·98
Al_2O_3	11·66	11·50	11·79	11·80	11·69	12·51
Fe_2O_3	3·26	3·11	2·98	2·83	3·04	2·83
FeO	11·31	11·35	11·72	11·86	11·56	11·71
MnO	0·22	0·24	0·22	0·24	0·23	0·23
MgO	5·01	4·91	4·79	5·13	4·96	5·42
CaO	10·44	10·60	10·54	10·36	10·49	10·00
Na_2O	2·27	2·55	2·46	2·75	2·51	2·65
K_2O	0·70	0·63	0·78	0·63	0·68	0·30
H_2O+	1·82	1·70	1·40	1·08	1·50	0·95
H_2O-	1·08	0·92	0·80	0·52	0·83	0·24
TiO_2	3·20	3·34	3·18	3·20	3·23	2·27
P_2O_5	0·37	0·25	0·33	0·28	0·31	0·37
TOTAL	100·40	100·30	100·07	100·46	100·31	99·55*
Specific gravity	2·935	2·948	3·00	3·007	2·972	2·975

The first point that strikes one about these four analyses is the extraordinary closeness in composition of the four rock-specimens, the maximum departure of any constituent from the mean being 0·50 per cent. (SiO_2). From this one is entitled to deduce not

* Includes SO_3, 0·09.

only that the specimens were fresh, but that each specimen represented clearly the composition of the flow from which it was taken, in spite of the fact that two of the specimens were dolerites, and two of them basalts, representing on the average different levels in flows of standard range of texture[1], the dolerites corresponding more closely with the middle section of the typical flow than the basalts.

Remembering that the first and third analyses represent olivine-dolerites and the second and fourth analyses basalts in which olivine is extremely scarce or absent, one can compare the analyses to see if either difference of mineral composition (*i.e.*, mode) or of texture is represented by any appreciable difference in the corresponding chemical analyses. The means are as follows:—

	Two olivine-dolerites.	Two basalts.
	Per cent.	Per cent.
SiO_2	49·07	49·49
Al_2O_3	11·72	11·65
Fe_2O_3	3·12	2·97
FeO	11·52	11·61
MnO	0·22	0·24
MgO	4·90	5·02
CaO	10·49	10·48
Na_2O	2·36	2·65
K_2O	0·74	0·63
H_2O+	1·61	1·39
H_2O-	0·94	0·72
TiO_2	3·19	3·27
P_2O_5	0·35	0·26
TOTAL	100·23	100·38
Specific gravity	2·967	2·97

Taking notice of differences only in those constituents in which both members of the pair providing the average figure vary in the same direction from both members of the other pair, the chief difference between the average composition of the dolerites and the basalts are that the dolerites are *lower* in SiO_2 (0·42), MnO (0·02), Na_2O (0·29) and TiO_2 (0·08), and *higher* in K_2O (0·11) and P_2O_5 (0·09). The presence or absence of olivine is not reflected in any significant variation in the amount of MgO. Whether the lava has consolidated as an olivine-dolerite or a basalt is, therefore,

[1] Fermor & Fox, *Rec. Geol. Surv. Ind.*, XLVII, p. 99, (1916).

apparently due not to differences in chemical composition and thus can be due only to differences in conditions of consolidation. The slower cooling of the doleritic sections of the interior of flows has not even resulted in a markedly greater approach to a holocrystalline texture, but only to the mineral units including the interstitial glass being on a coarser scale, and to the appearance of olivines.[1] The formation of palagonite, both delessitic and chlorophaeitic, must be regarded as a late magmatic change occurring within the flow during consolidation, and effected by the magmatic water contained in the flows.[2] It is suitable that the average total water in the dolerites is somewhat higher than in the basalts, where the opportunity for escape must have been greater.

It is, in fact, not until one calculates the norms of these rocks that can one detect any appreciable difference between the four flows. The norms are as follows :—

—	Flow 1. 24/151.	Flow 2A. 24/171.	Flow 2. 24/124.	Flow 3. 42/331.	Mean of the four (Raoult).	Flow 3. 26/172 (Washington).
Quartz	5·40	3·66	3·18	2·46	3·60	3·54
Orthoclase	3·89	3·89	4·45	3·89	3·89	1·67
Albite	19·39	21·48	20·96	23·06	20·96	22·53
Anorthite	19·46	18·07	18·90	18·07	18·90	21·41
Diopside	24·18	27·19	26·35	26·54	26·28	20·78
Hypersthene	13·70	12·00	13·00	14·12	13·20	18·86
Magnetite	4·64	4·41	4·41	4·18	4·41	4·18
Ilmenite	6·08	6·23	6·08	6·08	6·08	4·41
Apatite	0·93	0·62	0·62	0·62	0·62	0·93
H_2O+	1·82	1·70	1·40	1·08	1·58	0·95
H_2O-	1·08	0·92	0·80	0·52	0·83	0·24
SO_3	..	..	..	..	..	0·09
TOTAL	100·57	100·17	100·15	100·62	100·35	99·59
TOTAL ALKALI-FELSPARS	23·28	25·37	25·41	26·95	24·85	24·20
TOTAL FELSPARS	42·74	43·44	44·31	45·02	43·75	45·61
TOTAL PYROXENES	37·88	39·19	39·35	40·66	39·48	39·64
TOTAL IRON-ORES	10·72	10·64	10·49	10·26	10·49	8·59
TOTAL WATER	2·90	2·52	2·20	1·60	2·41	1·19
Specific gravity	2·935	2·948	3·00	3·007	2·972	2·975

[1] The presence of olivine in the doleritic section of a flow might be due either to gravitative settling from the upper basaltic section of a flow, in which case the olivine was probably intra-telluric in origin as has been deduced from the Bhusawal flows [*Rec. Geol. Surv. Ind.*, LVIII, pp. 200, 203, (1925)], or to the local conditions of consolidation, in which case the olivine was not intra-telluric. In the present case, the absence of appreciable chemical difference between the doleritic and basaltic flows supports the view that here the olivine is not intra-telluric.

[2] As was also deduced for the Bhusawal flows : *Rec. Geol. Surv. Ind.*, LVIII, p. 212, (1925).

The calculations have been made in accordance with the methods described in the 'Quantitative Classification of Igneous Rocks' 1903, utilising the tables of molecular proportions given therein. These norms differ from the modal composition of the rocks in the following points: they all show quartz, which has not been detected in the mode; consequently they show no olivine, which is seen prominently in two and rarely in a third rock in the mode; the total of alkali felspars is slightly in excess of the anorthite, corresponding, if the whole of this material were in the plagioclase, to a felspar slightly more acid than Ab_1An_1, whereas the plagioclase is a labradorite somewhat more basic than Ab_1 An_1; further the norm shows, of course, no interstitial glass. I have shown the water as an additional constituent in the norm as at least a portion of this was presumably a part of the magma. The differences between the norm and the mode are probably largely due to the interstitial glass in the latter, which may have contained a portion of the alkalies, any surplus SiO_2, and some water, in addition to other constituents. The water shown, especially that driven off above 105° C., was available in the rocks as the latter cooled to effect late magmatic changes, such as the formation of chlorophaeite and delessite. Each 1 per cent. of water in the rock is equivalent to about 4 per cent. of chlorophaeite or 7 to 8 per cent. of delessite.

On comparing the four norms of flows 1, 2A, 2 and 3 (Raoult's analyses), one observes, which was not anticipated, that there is a small but definite change in normative composition from below upwards. The normative quartz decreases progressively, the orthoclase remains constant, the albite increases almost regularly, whilst the water (both total and +105°) decreases regularly. Grouping certain minerals together, the total alkali felspars, as well as the total of alkali plus lime felspars, increase steadily, as also do the total pyroxenes. The total iron-ores fall very slowly.

These changes in the norm are so regular that it seems not unlikely that they point to a regular progressive change in the composition of the liquid in the magma-reservoir from which these flows were derived. The change takes the form of a steady decrease in the normative quartz and total iron-ores, and a continuous increase in the total alkali-felspars, total alkali plus lime felspars, and total pyroxenes.

These results indicate the importance of the norms in detecting progressive changes in the composition of a magma, in cases where the rocks are so similar that neither the chemical analyses nor the

rocks as observed under the microscope show any significant directional change of composition.

The failure of Washington's analysis, either as such or when calculated into the norm, to agree with the present analysis of the same flow, or to fall into its proper place in the series of norms, may indicate either that the specimen sent to Washington for analysis was not collected with the same care as my four specimens, or that the technique of Washington's analytical work differed in some respect from that of Raoult in Paris, so as to produce a small but definite difference in certain constituents. Compared with the rocks analysed in Paris, Washington's analysis is markedly low in K_2O, TiO_2, and water, and high in Al_2O_3. As a result the norm corresponding to Washington's analysis is low in orthoclase, ilmenite and water, and high in anorthite, with less diopside and more hypersthene.

IV. DISCUSSION OF WASHINGTON'S ANALYSES OF DECCAN TRAPS.

The subject is perhaps not strictly germane to the present paper, but the opportunity is suitable for discussing the 11 analyses of Deccan traps shown in Washingto's Tֺable I.[1] The mean of the 11 analyses is also shown in thisn table.

In the first place, No. 21 from the Rajmahal hills does not belong to the Deccan trap, but to the Rajmahal trap, which is considered to be of Jurassic instead of Uppermost Cretaceous age.

The remaining ten analyses can be arranged into two main groups. Four of them, namely 15, 16, 13, and 12, represent flows in the Satpura hills of the Central Provinces, all from localities that I have personally visited, and localities where the Deccan trap flows belong to the basal section of this formation, as do the four flows from the Linga tract already discussed in this present paper. Of the remaining six, the Rajahmundry analysis can be set aside as coming from an outlier of the Trap very distant from the main spread of the Deccan trap formation. Of the remaining five analyses four belong to the Bombay Presidency and probably to the Upper Traps, whilst the fifth belongs to Central India. The four Bombay specimens may be divided into two groups on the basis of their TiO_2 contents, the Kolhapur, Bombay Island and Cutch specimens all showing low TiO_2, whilst the specimen from Igatpuri is high in TiO_2. Excluding Washington's analysis of Rajmahal trap, the remaining analyses can be grouped as follows:—

[1] *Loc. cit.*, p. 774.

	Lower traps (C. P.).					Upper traps (Bombay).						
Washington's No.	15.	16.	13.	12.	Mean of four C. P. speci-mens.	8.	6.	1.	Mean of 8, 6, 1.	5.	4.	23.
G. S. I. No.	28/557.	28/558.	26/172.	27/165.		30/366.	1/503.	3/159.		16/757.	28/556,	29/321.
Locality.	Padmi Mandla, C. P.	Pipar-dahi, Seoni, C. P.	Bhaura-meta Hill, Chhind-wara, C. P.	Deondia Hill, Betul, C. P.		Kolha-pur, Bombay.	Bombay Island, Bombay.	Cutch, Bombay.		Igatpuri, Nasik district, Bombay.	Jiran, Nee-much, C. I.	Raja-mundry, Madras.
SiO_2	49·38	48·84	49·98	49·83	49·51	48·62	52·98	53·46	51·69	50·12	50·12	49·90
Al_2O_3	13·49	14·37	12·51	11·83	13·05	14·12	14·53	15·50	14·72	12·33	13·52	11·98
Fe_2O_3	3·67	2·63	2·83	3·14	3·96	2·29	3·38	2·81	2·83	4·53	3·99	4·55
FeO	8·94	10·00	11·71	10·92	10·39	12·40	10·05	10·17	10·87	8·04	9·19	9·83
MnO	0·21	0·22	0·23	0·21	0·22	0·21	0·04	0·07	0·11	0·14	0·18	0·15
MgO	6·48	5·33	5·42	5·60	5·71	5·29	3·66	3·59	4·18	7·54	5·42	5·89
CaO	11·26	9·82	10·00	9·66	10·18	9·49	7·49	7·61	8·20	9·57	9·97	9·80
Na_2O	1·68	2·26	2·65	2·39	2·25	2·95	3·43	3·37	3·25	2·20	2·42	2·23
K_2O	0·72	0·52	0·30	0·52	0·51	0·60	1·34	0·84	0·93	0·92	0·56	0·47
H_2O	1·42	2·50	0·95	3·09	1·99	2·28	1·88	1·87	2·01	0·70	1·46	0·87
H_2O	0·24	0·44	0·24	0·35	0·32	0·62	0·48	0·63	0·58	0·81	0·14	0·33
TiO_2	2·16	2·63	2·27	2·29	2·34	0·88	0·62	0·40	0·63	3·06	2·46	3·76
P_2O_5	0·46	0·36	0·37	0·30	0·37	0·30	0·64	0·31	0·42	0·32	0·29	0·21
BaO	..	..	*Nil*	..	..	..	..	..	..	..	0·03	..
SO_3	..	..	0·09	..	0·02	..	..	..	..	..	0·09	..
Total	100·11	99·92	99·55	100·13	99·92	100·06	100·52	100·63	100·42	100·18	99·84	99·97
Specific gravity	2·926	2·927	2·975	3·006	2·959	3·050	2·831	2·855	2·912	2·954	2·903	2·986

Comparing the mean of the four Lower Traps from the Central Provinces with the mean of the three low-titania Upper Traps from Bombay, we see that the Upper Traps show higher SiO_2 and Al_2O_3 and lower MnO, MgO, CaO and TiO_2 than the Lower Traps. The total iron and the water contents are substantially the same. The Igatpuri specimen, though coming from a high altitude and undoubtedly to be referred to the Upper Traps, is close to the Lower Traps in composition, differing significantly therefrom only in its high MgO and K_2O.

By comparing with the two averages of the Lower Traps and Upper Traps it is seen that both the Central Indian rock and the specimen from Rajamundry in Madras are closely allied in composition to the Lower Traps and significantly different from the Upper Traps. Thus whilst the Central Indian analysis shows no important difference from the Lower Traps of the Central Provinces, it is low in SiO_2, Al_2O_3, Na_2O, and K_2O, and high in MnO and TiO_2 as compared with the Upper Traps of Bombay. Similarly the Rajamundry analysis differs from the C. P. Lower Traps only in being low in Al_2O_3 and water and higher in TiO_2; whilst from the Upper Traps of Bombay it differs by being low in SiO_2, still lower in Al_2O_3, low in Na_2O, K_2O and water, and high in MgO and CaO, and very high in TiO_2.

If analyses can be utilised as a guide then undoubtedly the Rajamundry trap and the Central Indian trap belong to the Lower Traps.

The following table shows the analyses and norms corresponding to the various groups of Washington's analyses shown above, and also to the average of Raoult's four analyses :—

	LOWER TRAPS.		UPPER TRAPS.		LOWER TRAPS.	
—	MEAN OF RAOULT'S 4 ANALYSES.	MEAN OF 4 ANALYSES (WASHINGTON).	MEAN OF 3 ANALYSES (WASHINGTON).	ONE ANALYSIS (WASHINGTON).	ONE ANALYSIS (WASHINGTON).	ONE ANALYSIS (WASHINGTON).
	Chhindwara district, C. P.	Four districts of the C. P.	Bombay Presidency.	Igatpuri, Bombay Presidency.	Nimach, C. I.	Rajamundry, Madras.
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Analyses.						
SiO_2	49·28	49·51	51·69	50·12	50·12	49·90
Al_2O_3	11·69	13·05	14·72	12·83	13·52	11·98
Fe_2O_3	3·04	3·06	2·83	4·53	3·09	4·55
FeO	11·56	10·39	10·87	8·04	9·19	9·83
MnO	0·23	0·22	0·11	0·14	0·18	0·15
MgO	4·96	5·71	4·18	7·54	5·42	5·89
CaO	10·49	10·18	8·20	9·57	9·97	9·80
Na_2O	2·51	2·25	3·25	2·20	2·42	2·23
K_2O	0·68	0·51	0·93	0·92	0·56	0·47
H_2O+	1·50	1·99	2·01	0·70	1·46	0·89
H_2O-	0·83	0·32	0·58	0·81	0·14	0·33
TiO_2	3·23	2·34	0·63	3·06	2·46	3·76
P_2O_5	0·31	0·37	0·42	0·22	0·29	0·21
TOTAL	100·31	99·92*	100·42	100·18	99·84†	99·97
TOTAL $Al_2O_3+TiO_2$	14·92	15·39	15·35	15·89	15·98	15·74
TOTAL FeO_3+FeO	14·60	13·45	13·70	12·57	13·18	14·38
Na_2O+K_2O	3·19	2·76	4·18	3·12	2·98	2·70
K_2O+Na_2O	·271	0·226	0·280	0·418	0·231	0·211
Norms.						
Quartz	3·60	4·68	2·40	5·34	5·76	7·74
Orthoclase	3·89	2·78	5·56	5·56	3·34	2·78
Albite	20·96	18·86	27·25	18·34	20·44	18·86
Anorthite	18·90	24·19	22·80	21·13	24·19	21·49
Diopside	26·28	10·70	12·84	19·80	19·32	20·73
Hypersthene	13·20	17·65	20·57	15·53	13·94	12·49
Magnetite	4·41	4·41	4·18	6·50	5·80	6·50
Ilmenite	6·08	4·41	1·22	5·93	4·71	7·14
Apatite	0·62	0·93	0·93	0·62	0·62	0·62
H_2O+	1·58	1·99	2·01	0·70	1·46	0·87
H_2O-	0·83	0·32	0·58	0·81	0·14	0·33
TOTAL	100·35	99·92	100·34	100·26	99·84‡	99·46
Specific gravity	2·972	29·59	2·012	2·954	2·903	2·986
TOTAL ALKALI-FELSPARS	24·85	21·64	32·81	23·90	23·78	21·64
TOTAL FELSPARS	43·75	45·83	55·61	45·03	47·97	43·04
TOTAL PYROXENES	39·48	37·35	33·41	35·33	33·26	33·22
TOTAL IRON-ORES	10·49	8·82	5·40	12·43	10·51	13·64
TOTAL WATER	2·41	2·31	2·59	1·51	1·60	1·20

* Including 0·02 SO_3.
† Including 0·03 BaO and 0·09 SO_3.
‡ Including 0·03 BaO and 0·09 SO_3.

V. SUMMARY AND CONCLUSIONS.

1. In a paper published in 1916, Dr. Fox and I gave an account, with a map, of the macroscopic aspects of five Deccan trap lava flows in the Linga tract of the Chhindwara district, Central Provinces.

2. Other work has prevented the laboratory study that was intended of the collections then made.

3. Specimens of four flows were, however, collected at the time for purposes of analysis, and these specimens have now been analysed by M. Raoult of Paris with the kind concurrence of Prof. A. Lacroix.

4. The four specimens representing, from below upwards, flows 1, 2A, 2 and 3, consisted alternatively of olivine-dolerites (flows 1 and 2) and basalts almost devoid of olivine (flows 2A and 3).

5. Apart from olivine, the minerals present in all four flows are acid labradorite, augite, iron-ore (ilmenite and magnetite), apatite and interstitial glass, with secondary palagonite (either chlorophaeitic or delessitic) regarded as late magmatic in origin and as, therefore, forming an integral part of the fresh rock.

6. In spite of the mineral and textural differences of the four rocks the analyses are remarkably close to one another, and in no chemical constituent do they show any substantial departure from the mean.

7. On calculating the norms of these four rocks it is found, however, that although they all fall into the same sub-range of the quantitative classification, namely camptonose (III, 5, 3, 4), yet there is a slight progressive change from below upwards. In terms of normative minerals there is a continuous decrease in quartz, total iron-ore (slight), and total water, and a continuous increase in alkali-felspars and total pyroxenes (slight). These point to corresponding slight changes in the composition of the residual magma after each eruption.

8. The fact that the four analyses are so similar, and yet when thus interpreted can be shown to indicate a subtle progressive change in the magma, must be held to mean that in the case of a lava flow that has been very fluid and therefore well mixed, and yet has subsequently cooled fairly quickly, so that substantial changes of bulk composition have not been produced by gravitative settling of the first-formed minerals, then each carefully selected fresh specimen can be utilised to give a fair idea of the chemical composition of the

whole flow. The alternative is to regard the results yielded by the four analyses as due to a lucky fortuitous selection of four specimens in the field, which seems highly improbable.

9. As one of the specimens included in Washington's study of Deccan traps is from one of the Linga flows studied in this paper (flow 3), a comparison between the two sets of analyses is rendered possible on the assumption that the specimen sent to Washington was as carefully selected as those sent to Raoult. The most marked difference between the two analyses is that Raoult's analysis shows 0·71 per cent. less Al_2O_3 and 0·93 per cent. more TiO_2. As the four flows as represented by Raoult's four analyses range in Al_2O_3 contents only between 11·50 and 11·80 per cent. and in TiO_2 contents only between 3·18 and 3·34 per cent., whilst Washington's values are 12·51 per cent. and 2·27 per cent. respectively, it is possible that there is a difference in chemical technique between the two laboratories so that in one case TiO_2 is included with Al_2O_3 or *vice versa.*

10. After excluding one of Washington's eleven analyses as representing the Rajmahal traps (Jurassic) and not the Deccan traps (Upper Cretaceous), the remaining ten analyses are arranged on geographical grounds into two groups representing respectively the Lower Traps and the Upper Traps. On the whole the Lower Traps are lower in SiO_2, Al_2O_3, and alkalies, and higher in MnO and TiO_2, than the Upper Traps. Comparing the mean of Washington's four analyses of Deccan traps from the Lower Traps of the Central Provinces, with the mean of three analyses of Deccan traps from the Upper Traps of the Bombay Presidency, it is seen, on converting these analyses into the corresponding norms, that the differences correspond in direction, except in one constituent, with the small progressive changes detected in the four Linga flows as follows :--

—	RAOULT'S ANALYSES. LINGA FLOWS, C. P. (LOWER TRAPS).		WASHINGTON'S ANALYSES.	
	Bottom flow.	Top flow.	Four Lower Traps, C. P.	Three Upper Traps, Bombay.
	Per cent.	Per cent.	Per cent.	Per cent.
Quartz	5·40	2·46	4·68	2·40
Total alkali-felspars	23·28	26·95	21·64	32·81
Total felspars	42·74	45·02	45·83	55·01
Total pyroxenes	37·88	40·66	37·35	33·41
Total iron-ores	10·72	10·26	8·82	5·40

In both sets the quartz and total iron-ores fall as one passes upwards in the Trap series, whilst the total alkali felspars and the total felspars rise, the difference between the total felspars of the Lower and Upper Traps and between the total iron-ores of the Lower and Upper Traps being much greater than between the lowest and the highest of the Linga traps. The pyroxenes in the two cases have, however, changed in opposite directions, due to substantially lower CaO in the Upper Traps as compared with the Lower Traps.

On the whole it is evident that the progressive changes shown in the norm of the four Linga flows represent on a minor scale the progressive change in composition of the Deccan trap flows as a whole from Lower to Upper Traps leading to a progressive modification of the magma with increasing alkalies and alumina, a trend which may have possibly resulted in the formation of the acid and alkaline rocks of Kathiawar and Pavagadh Hill.

11. From a comparison of two analyses of traps from Rajamundry and Central India with the means for Lower Traps and Upper Traps, it is deduced that these two rocks probably belong to the Lower Traps. In making this deduction a certain amount of caution is necessary, because one of the analyses of Upper Traps (Igatpuri) is in many respects similar to those of the Lower Traps. The abnormally high MgO and K_2O seem, however, to distinguish the Igatpuri specimen from the otherwise chemically similar Lower Traps.

EXPLANATION OF PLATE.

PLATE 23. Photomicrographs :—

FIG. 1. Olivine-dolerite (flow 1) from Goreyghat. Microscope slide 23356 × 34.

FIG. 2. Basalt (flow 2A) from Bisapur Khurd. Microscope slide 23357 × 34.

FIG. 3. Olivine-dolerite (flow 2) from Kulbehra River. Microscope slide 23358 × 34.

FIG. 4. Basalt (flow 3) from Shikarpur. Microscope slide 23359 × 34.

MISCELLANEOUS NOTE

Quarterly Statistics of Production of Coal, Gold and Petroleum in India : April to June, 1934.

Coal.

—	April.	May.	June.	Quarterly total for each Province.
	Tons.	Tons.	Tons.	Tons.
Assam	13,497	14,872	13,282	41,651
Baluchistan	1,479	1,737	645	3,861
Bengal	518,831	543,584	486,913	1,549,328
Bihar and Orissa . . .	1,032,843	1,104,035	1,018,145	3,155,023
Central Provinces . . .	125,516	123,226	109,608	388,350
Punjab	11,688	15,226	12,000	38,914
TOTAL .	1,703,854	1,802,680	1,640,593	5,147,127

Gold.

—	April.	May.	June.	Quarterly total for each Company.
	Ozs.	Ozs.	Ozs.	Ozs.
The Mysore Gold Mining Co., Ltd.	7,532	7,784	7,539	22,855
The Champion Reef Gold Mines of India, Ltd.	5,302	5,614	5,601	16,517
The Ooregaum Gold Mining Company of India, Ltd.	4,038	4,195	4,200	12,433
The Nundydroog Mines, Ltd. .	9,247	9,449	9,229	27,925
TOTAL .	26,119	27,042	26,569	79,730

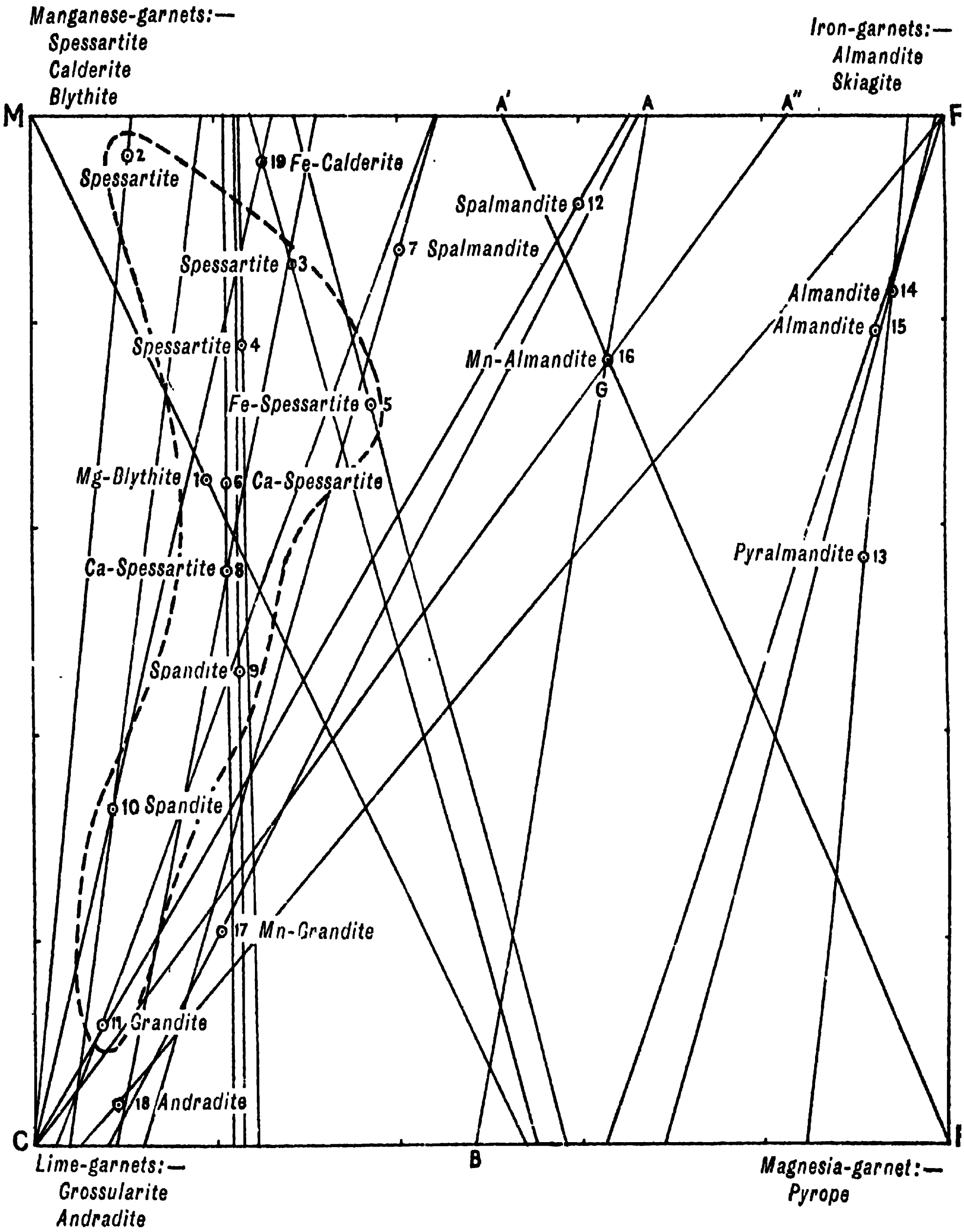
Petroleum.

—	Petroleum.	Petrol.
	Gallons.	Gallons.
Assam	15,243,951	*Nil.*
Burma	64,611,826	2,090,469
Punjab	836,000	130,136
TOTAL	80,691,777	2,220,605

L. L. FERMOR.

MGIPC—M—VIII-4-17—2-10-34—850.

Records, Vol. LXVIII, Pl. 22.



G. S. I., Calcutta.

DIAGRAM ILLUSTRATING THE COMPOSITION OF INDIAN GARNETS.

Records, Vol. LXVIII, Pl. 23.

FIG. 1.—24·151: slide 23356. (× 34).
FLOW 1. OLIVINE-DOLERITE, Goreyghat.

FIG. 2.—24·171: slide 23357. (× 34).
FLOW 2 A. BASALT, Bisapur Khurd.

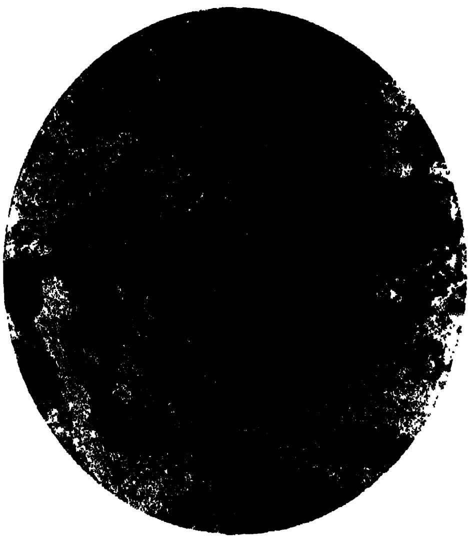


FIG. 3.—24·124: slide 23358. (× 34).
FLOW 2. OLIVINE-DOLERITE, near Dewardha.

FIG. 4.—42·331: slide 23359. (× 34).
FLOW 3. BASALT, Shikarpur quarry.

M. S. Krishnan & S. N. Das, photomicros.

G. S. I., Calcutta.

Vol. X, 1877.

Part 1 (out of print).—Annual report for 1876. Geological notes on Great Indian Desert between Sind and Rajputana. Cretaceous genus Omphalia near Nameho lake, Tibet, about 75 miles north of Lhassa. Estheria in Gondwana formation. Vertebrata from Indian tertiary and secondary rocks. New Emydine from the upper tertiaries of Northern Punjab. Observations on under-ground temperature.

Part 2 (out of print).—Rocks of the Lower Godavari. 'Atgarh Sandstones' near Cuttack. Fossil floras in India. New or rare mammals from the Siwaliks. Aravali series in North-Eastern Rajputana. Borings for coal in India. Geology of India.

Part 3 (out of print).—Tertiary zone and underlying rocks in North-West Punjab. Fossil floras in India. Erratics in Potwar. Coal explorations in Darjiling district. Limestones in neighbourhood of Barakar. Forms of blowing machine used by smiths of Upper Assam. Analyses of Raniganj coals.

Part 4 (out of print).—Geology of Mahanadi basin and its vicinity. Diamonds, gold, and lead ores of Sambalpur district. 'Eryon Comp. Barrovensis', McCoy, from Sripermatur group near Madras. Fossil floras in India. The Blaini group and 'Central Gneiss' in Simla, Himalayas. Tertiaries of North-West Punjab. Genera Chœromeryx and Rhagatherium.

Vol. XI, 1878.

Part 1.—Annual report for 1877. Geology of Upper Godavari basin, between river Wardha and Godavari, near Sironcha. Geology of Kashmir, Kishtwar, and Pangi. Siwalik mammals. Palæontological relations of Gondwana system. 'Erratics in Punjab.'

Part 2 (out of print).—Geology of Sind (second notice). Origin of Kumaun lakes. Trip over Milam Pass, Kumaun. Mud volcanoes of Ramri and Cheduba. Mineral resources of Ramri, Cheduba and adjacent islands.

Part 3 (out of print).—Gold industry in Wynaad. Upper Gondwana series in Trichinopoly and Nellore-Kistna districts. Senarmontite from Sarawak.

Part 4.—Geographical distribution of fossil organisms in India. Submerged forest on Bombay Island.

Vol. XII, 1879.

Part 1.—Annual report for 1878. Geology of Kashmir (third notice). Siwalik mammalia, Siwalik beds. Tour through Hangrang and Spiti. Mud eruption in Ramri Island (Arakan). Braunite, with Rhodonite, from Nagpur, Central Provinces. Palæontological notes from Satpura coal-basin. Coal importations into India.

Part 2 (out of print).—Mohpani coal-field. Pyrolusite with Psilomelane at Gosalpur, Jabalpur district. Geological reconnaissance from Indus at Kushalgarh to Kurram at Thal on Afghan frontier. Geology of Upper Punjab.

Part 3 (out of print).—Geological features of northern Madura, Padukota State, and southern parts of Tanjore and Trichinopoly districts included within limits of sheet 80 of Indian Atlas. Cretaceous fossils from Trichinopoly district, collected in 1877-78. Sphenophyllum and other Equisetaceæ with reference to Indian form Trizygia Speciosa, Royle (Sphenophyllum Trizygia, Ung.). Mysorin and Atacamite from Nellore district. Corundum from Khasi Hills. Joga neighbourhood and old mines on Nerbadda.

Part 4.—'Attock Slates' and their probable geological position. Marginal bone of undescribed tortoise, from Upper Siwaliks, near Nila, in Potwar, Punjab. Geology of North Arcot district. Road section from Murree to Abbottabad.

Vol. XIII, 1880.

Part 1.—Annual report for 1879. Geology of Upper Godavari basin in neighbourhood of Sironcha. Geology of Ladak and neighbouring districts. Teeth of fossil fishes from Ramri Island and Punjab. Fossil genera Nöggerathia, Stbg., Nöggerathiopsis, Fstm., and Rhiptozamites, Schmalh., in palæozoic and secondary rocks of Europe, Asia and Australia. Fossil plants from Kattywar, Shekh Budin, and Sirgujah. Volcanic foci of eruption in Konkan.

Part 2.—Geological notes. Palæontological notes on lower trias of Himalayas. Artesian wells at Pondicherry, and possibility of finding sources of water-supply at Madras.

Part 3.—Kumaun lakes. Celt of palæolithic type in Punjab. Palæontological notes from Karharbari and South Rewa coal-fields. Correlation of Gondwana flora with other floras. Artesian wells at Pondicherry. Salt in Rajputana. Gas and mud eruptions on Arakan coast on 12th March 1879 and in June 1843.

Part 4 (out of print).—Pleistocene deposits of Northern Punjab, and evidence they afford of extreme climate during portion of that period. Useful minerals of Arvali region. Correlation of Gondwana flora with that of Australian coal-bearing system. Reh or alkali soils and saline well waters. Reh soils of Upper India. Naini Tal landslip, 18th September 1880.

Vol. XIV, 1881.

Part 1.—Annual report for 1880. Geology of part of Dardistan, Baltistan, and neighbouring districts. Siwalik carnivora. Siwalik group of Sub-Himalayan region. South Rewah Gondwana basin. Ferruginous beds associated with basaltic rocks of north-eastern Ulster, in relation to Indian laterite. Rajmahal plants. Travelled blocks of the Punjab. Appendix to 'Palæontological notes on lower trias of Himalayas'. Mammalian fossils from Perim Island.

Part 2 (out of print).—Nahan-Siwalik unconformity in North-Western Himalaya. Gondwana vertebrates. Ossiferous beds of Hundes in Tibet. Mining records and mining record office of Great Britain; and Coal and Metalliferous Mines Act of 1872 (England). Cobaltite and danatite from Khetri mines, Rajputana; with remarks on Jaipurite (Syepoorite) Zinc-ore (Smithsonite and Blende) with barytes in Karnul districts, Madras. Mud eruption in island of Cheduba.

Part 3 (out of print).—Artesian borings in India. Oligoclase granite at Wangtu on Sutlej, North-West Himalayas. Fish-plate from Siwaliks. Palæontological notes from Hazaribagh and Lohardagga districts. Fossil carnivora from Siwalik hills.

Part 4 (out of print).—Unification of geological nomenclature and cartography. Geology of Aravali region, central and eastern. Native antimony obtained at Pulo Obin, near Singapore. Turgite from Juggiapett, Kistnah District, and zinc carbonate from Karnul, Madras. Section from Dalhousie to Pangi, *viâ* Sach Pass. South Rewah Gondwana basin. Submerged forest on Bombay Island.

Vol. XV, 1882.

Part 1 (out of print).—Annual report for 1881. Geology of North-West Kashmir and Khagan. Gondwana labyrinthodonts (Siwalik and Jamna mammals). Geology of Dalhousie, North-West Himalaya. Palm leaves from (tertiary) Murree and Kasauli beds in India. Iridosmine from Noa-Dihing river, Upper Assam, and Platinum from Chutia Nagpur. On (1) copper mine near Yongri hill, Darjiling district: (2) arsenical pyrites in same neighbourhood; (3) kaolin at Darjiling. Analyses of coal and fire-clay from Makum coal-field, Upper Assam. Experiments on coal of Pind Dadun Khan, Salt-range, with reference to production of gas, made April 29th, 1881. International Congress of Bologna.

Part 2 (out of print).—Geology of Travancore State. Warkilli beds and reported associated deposits at Quilon, in Travancore. Siwalik and Narbada fossils. Coal-bearing rocks of Upper Rer and Mand rivers in Western Chutia Nagpur. Pench river coal-field in Chhindwara district, Central Provinces. Boring for coal at Engsein, British Burma. Sapphires in North-Western Himalaya. Eruption of mud volcanoes in Cheduba.

Part 3 (out of print).—Coal of Mach (Much) in Bolan Pass, and of Sharigh on Harnai route between Sibi and Quetta. Crystals of stilbite from Western Ghats, Bombay. Traps of Darang and Mandi in North-Western Himalayas. Connexion between Hazara and Kashmir series. Umaria coal-field (South Rewah Gondwana basin). Daranggiri coal-field, Garo Hills, Assam. Coal in Myanoung division, Henzada district.

Part 4 (out of print).—Coal-fields of Mysore. Borings for coal at Beddadanol, Godavari district, in 1874. Supposed occurrence of coal on Kistna.

Vol. XVI, 1883.

Part 1.—Annual report for 1882. Richthofenia, Kays. (Anomia Lawrenciana, Koninck). Geology of South Travancore. Geology of Chamba. Basalts of Bombay.

Part 2 (out of print).—Synopsis of fossil vertebrata of India. Bijori Labyrinthodont Skull of Hippotherium antilopinum. Iron ores, and subsidiary materials for manufacture of iron, in north-eastern part of Jabalpur district. Laterite and other manganese-ore occurring at Gosulpore, Jabalpur district. Umaria coal-field.

Part 3 (out of print).—Microscopic structure of some Dalhousie rocks. Lavas of Aden. Probable occurrence of Siwalik strata in China and Japan. Mastodon angustidens in India. Traverse between Almora and Mussoorree. Cretaceous coal-measures at Borsora in Khasia Hills, near Laour in Sylhet.

Part 4 (out of print).—Palæontological notes from Daltonganj and Hutar coal-fields in Chota Nagpur. Altered basalts of Dalhousie region in North-Western Himalayas. Microscopic structure of some Sub-Himalayan rocks of tertiary age. Geology of Jaunsar and Lower Himalayas. Traverse through Eastern Khasia, Jaintia, and North Cachar Hills. Native lead from Maulmain and chromite from the Andaman Islands. Fiery eruption from one of the mud volcanoes of Cheduba Island, Arakan. Irrigation from wells in North-Western Provinces and Oudh.

Vol. XVII, 1884.

Part 1 (*out of print*).—Annual report for 1883. Smooth-water anchorages or mud-banks of Narrakal and Alleppy on Travancore coast. Billa Surgam and other caves in Karnool district. Geology of Chuari and Sihunta parganas of Chamba. Lyttonia, Waagen, in Kuling series of Kashmir.

Part 2 (*out of print*).—Earthquake of 31st December 1881. Microscopic structure of some Himalayan granites and gneissose granites. Choi coal exploration. Re-discovery of fossils in Siwalik beds. Mineral resources of Andaman Islands in neighbourhood of Port Blair. Intertrappean beds in Deccan and Laramie group in Western North America.

Part 3 (*out of print*).—Microscopic structure of some Aravali rocks. Section along Indus from Peshawar Valley to Salt-range. Sites for boring in Raigarh-Hingir coal-field (first notice). Lignite near Raipore, Central Provinces. Turquoise mines of Nishâpûr, Khorassan. Fiery eruption from Minbyin mud volcano of Cheduba Island, Arakan. Langrin coal-field, South-West Khasia Hills. Umaria coal-field.

Part 4 (*out of print*).—Geology of part of Gangasulan pargana of British Garhwal. Slates and schists imbedded in gneissose granite of North-West Himalayas. Geology of Takht-i-Suleiman. Smooth-water anchorages of Travancore coast. Auroferous sands of the Subansiri river, Pondicherry lignite, and phosphatic rocks at Musuri. Billa Surgam caves.

Vol. XVIII, 1885.

Part 1 (*out of print*).—Annual report for 1884. Country between Singareni coal-field and Kistna river. Geological sketch of country between Singareni coal-field and Hyderabad. Coal and limestone in Doigrung river near Golaghat, Assam. Homotaxis, as illustrated from Indian formations. Afghan field notes.

Part 2.—Fossiliferous series in Lower Himalaya, Garhwal. Age of Mandhali series in Lower Himalaya. Siwalik camel (Camelus Antiquus, nobis ex Falc. and Caut. MS.). Geology of Chamba. Probability of obtaining water by means of artesian wells in plains of Upper India. Artesian sources in plains of Upper India. Geology of Aka Hills. Alleged tendency of Arakan mud volcanoes to burst into eruption most frequently during rains. Analyses of phosphatic nodules and rock from Mussooree.

Part 3 (*out of print*).—Geology of Andaman Islands. Third species of Merycopotamus. Percolation as affected by current. Pirthala and Chandpur meteorites. Oil-wells and coal in Thayetmyo district, British Burma. Antimony deposits in Maulmain district. Kashmir earthquake of 30th May 1885. Bengal earthquake of 14th July 1885.

Part 4 (*out of print*).—Geological work in Chhattisgarh division of Central Provinces. Bengal earthquake of 14th July 1885. Kashmir earthquake of 30th May 1885. Excavations in Billa Surgam caves. Nepaulite. Sabetmahet meteorite.

Vol. XIX, 1886.

Part 1 (*out of print*).—Annual report for 1885. International Geological Congress of Berlin. Palæozoic Fossils in Olive group of Salt-range. Correlation of Indian and Australian Coal-bearing beds. Afghan and Persian Field-notes. Section from Simla to Wangtu, and petrological character of Ambhibolites and Quartz-Diorites of Sutlej valley.

Part 2 (*out of print*).—Geology of parts of Bellary and Anantapur districts. Geology of Upper Dehing basin in Singpho Hills. Microscopic characters of eruption rocks from Central Himalayas. Mammalia of Karnul Caves. Prospects of finding coal in Western Rajputana. Olive group of Salt-range. Boulder-beds of Salt-range. Gondwana Homotaxis.

Part 3 (*out of print*).—Geological sketch of Vizagapatam district, Madras. Geology of Northern Jesalmer. Microscopic structure of Malani rocks of Arvali region. Malanjkhandi copper-ore in Balaghat district, C. P.

Part 4 (*out of print*).—Petroleum in India. Petroleum exploration at Khatan. Boring in Chhattisgarh coal-fields. Field-notes from Afghanistan: No. 3, Turkistan. Fiery eruption from one of the mud volcanoes of Cheduba Island, Arakan. Nammianthal aerolite. Analysis of gold dust from Meza valley, Upper Burma.

Vol. XX, 1887.

Part 1 (*out of print*).—Annual report for 1886. Field-notes from Afghanistan: No. 4, from Turkistan to India. Physical geology of West British Garhwal; with notes on a route traversed through Jaunsar-Bawar and Tiri-Garhwal. Geology of Garo Hills. Indian image-stones. Soundings recently taken off Barren Island and Narcondam. Talchir boulder-beds. Analysis of Phosphatic Nodules from Salt-range, Punjab.

Part 2.—Fossil vertebrata of India. Echinoidea of cretaceous series of Lower Narbada Valley. Field-notes: No. 5—to accompany geological sketch map of Afghanistan and North-Eastern Khorassan. Microscopic structure of Rajmahal and Deccan traps. Dolerite of Chor. Identity of Olive series in east, with speckled sandstone in west, of Salt-range in Punjab.

Part 3.—Retirement of Mr. Medlicott. J. B. Mushketoff's Geology of Russian Turkistan. Crystalline and metamorphic rocks of Lower Himalaya, Garhwal, and Kumaun, Section I. Geology of Simla and Jutogh. 'Lalitpur' meteorite.

Part 4 (out of print).—Points in Himalayan geology. Crystalline and Metamorphic rocks of Lower Himalaya, Garhwal, and Kumaon, Section II. Iron industry of western portion of Raipur. Notes on Upper Burma. Boring exploration in Chhattisgarh coal-field (Second notice). Pressure Metamorphism, with reference to foliation of Himalayan Gneissose Granite. Papers on Himalayan Geology and Microscopic Petrology.

Vol. XXI, 1888.

Part 1.—Annual report for 1887. Crystalline and metamorphic rocks of Lower Himalaya, Garhwal, and Kumaun, Section III. Birds'-nest of Elephant Island, Mergui Archipelago. Exploration of Jesalmer, with a view to discovery of coal. Facetted pebble from boulder-bed ('speckled sandstone') of Mount Chel in Salt-range, Punjab. Nodular stones obtained off Colombo.

Part 2 (out of print).—Award of Wollaston Gold Medal, Geological Society of London, 1888. Dharwar System in South India. Igneous rocks of Raipur and Balaghat, Central Provinces. Sangar Marg and Mohowgale coal-fields, Kashmir.

Part 3 (out of print).—Manganese Iron and Manganese Ores of Jabalpur. 'The Carboniferous Glacial Period.' Pre-tertiary sedimentary formations of Simla region of Lower Himalayas.

Part 4 (out of print).—Indian fossil vertebrates. Geology of North-West Himalayas. Blown-sand rock sculpture. Nummulites in Zanskar. Mica traps from Barakar and Raniganj.

Vol. XXII, 1889.

Part 1 (out of print).—Annual report for 1888. Dharwar System in South India. Wajra Karur diamonds, and M. Chaper's alleged discovery of diamonds in pegmatite. Generic position of so-called Plesiosaurus indicus. Flexible sandstone or Itacolumite, its nature, mode of occurrence in India, and cause of its flexibility. Siwalik and Narbada Chelonia.

Part 2 (out of print).—Indian Steatite. Distorted pebbles in Siwalik conglomerate, "Carboniferous Glacial Period." Notes on Dr. W. Waagen's "Carboniferous Glacial Period". Oil-fields of Twingoung and Beme, Burma. Gypsum of Nehal Nadi, Kumaun. Materials for pottery in neighbourhood of Jabalpur and Umaria.

Part 3 (out of print).—Coal outcrops in Sharigh Valley, Baluchistan. Trilobites in Neobolus beds of Salt-range. Geological notes. Cherra Poonjee coal-fields, in Khasia Hills. Cobaltiferous Matt from Nepál. President of Geological Society of London on International Geological Congress of 1888. Tin-mining in Mergui district.

Part 4 (out of print).—Land-tortoises of Siwaliks. Pelvis of a ruminant from Siwaliks. Assays from Sambhar Salt-Lake in Rajputana. Manganiferous iron and Manganese Ores of Jabalpur. Palagonite-bearing traps of Rájmahál hills and Deccan. Tin-smelting in Malay Peninsula. Provincial Index of Local Distribution of Important Minerals, Miscellaneous Minerals, Gem Stones and Quarry Stones in Indian Empire: Part 1.

Vol. XXIII, 1890.

Part 1 (out of print).—Annual report for 1889. Lakadong coal-fields, Jaintia Hills. Pectoral and pelvic girdles and skull of Indian Dicynodonts. Vertebrate remains from Nagpur district (with description of fish-skull). Crystalline and metamorphic rocks of Lower Himalayas, Garhwál and Kumaun, Section IV. Bivalves of Olive group, Salt-range. Mud-banks of Travancore coasts.

Part 2 (out of print).—Petroleum explorations in Harnai district, Baluchistan. Sapphire Mine of Kashmir. Supposed Matrix of Diamond at Wajra Karur, Madras. Sonapet Gold-field. Field-notes from Shan Hills (Upper Burma). New species of Syringosphæridæ.

Part 3 (out of print).—Geology and Economic Resources of Country adjoining Sind-Pishin Railway between Sharigh and Spintangi, and of country between it and Khattan. Journey through India in 1888-89, by Dr. Johannes Walther. Coal-fields of Lairungao, Maosandram, and Mao-be-lar-kar, in the Khasi Hills. Indian Steatite. Provincial Index of Local Distribution of Important Minerals, Miscellaneous Minerals, Gem Stones, and Quarry Stones in Indian Empire.

Part 4 (out of print).—Geological sketch of Naini Tal; with remarks on natural conditions governing mountain slopes. Fossil Indian Bird Bones. Darjiling Coal between Lisu and Ramthi rivers. Basic Eruptive Rocks of Kadapah Area. Deep Boring at Lucknow. Coal Seam of Dore Ravine, Hazara.

Vol. XXIV, 1891.

Part 1 (out of print).—Annual report for 1890. Geology of Salt-range of Punjab, with re-considered theory of Origin and Age of Salt-Marl. Graphite in decomposed Gneiss (Laterite) in Ceylon. Glaciers of Kabru, Pandim, etc. Salts of Sambhar Lake in Rajputana, and 'Reh' from Aligarh in North-Western Provinces. Analysis of Dolomite from Salt-range, Punjab.

Part 2 (out of print).—Oil near Moghal Kot, in Sheráni country, Suleiman Hills. Mineral Oil from Suleiman Hills. Geology of Lushai Hills. Coal-fields in Northern Shan States. Reported Namséka Ruby-Mine in Mainglôn State. Tourmaline (Schorl) Mines in Mainglôn State. Salt-range near Bawgyo, Thibaw State.

Part 3 (out of print).—Boring in Daltonganj Coal-field, Palamow. Death of Dr. P. Martin Duncan. Pyroxenic varieties of Gneiss and Scapolite-bearing Rocks.

Part 4 (out of print).—Mammalian Bones from Mongolia. Darjeeling Coal Exploration. Geology and Mineral Resources of Sikkim. Rocks from the Salt-range, Punjab.

Vol. XXV, 1892.

Part 1 (out of print).—Annual report for 1891. Geology of Thal Chotiáli and part of Mari country. Petrological Notes on Boulder-bed of Salt-range, Punjab. Sub-recent and Recent Deposits of valley plains of Quetta, Pishin, and Dashti-i-Bedalot; with appendices on Chamans of Quetta; and Artesian water-supply of Quetta and Pishin.

Part 2 (out of print).—Geology of Saféd-Kôh. Jherria Coal-field.

Part 3 (out of print).—Locality of Indian Tscheffkinite. Geological Sketch of country north of Bhamo. Economic resources of Amber and Jade mines area in Upper Burma. Iron-ores and Iron industries of Salem District. Riebeckite in India. Coal on Great Tenasserim River, Lower Burma.

Part 4 (out of print).—Oil Springs at Mogal Kot in Shirani Hills. Mineral Oil from Suleiman Hills. New Ambar-like Resin in Burma. Triassic Deposits of Salt-range.

Vol. XXVI, 1893.

Part 1 (out of print).—Annual report for 1892. Central Himalayas. Jadeite in Upper Burma. Burmite, new Fossil Resin from Upper Burma. Prospecting Operations, Mergui District, 1891-92.

Part 2 (out of print).—Earthquake in Baluchistan of 20th December 1892. Burmite, new amber-like fossils from Upper Burma. Alluvial deposits and Subterranean water-supply of Rangoon.

Part 3 (out of print).—Geology of Sherani Hills. Carboniferous Fossils from Tenasserim Boring at Chandernagore. Granite in Tavoy and Mergui.

Part 4 (out of print).—Geology of country between Chappar Rift and Harnai in Baluchistan Geology of part of Tenasserim Valley with special reference to Tendau-Kamapying Coal-field. Magnetite containing Manganese and Alumina. Hislopite.

Vol. XXVII, 1894.

Part 1 (out of print).—Annual report for 1893. Bhaganwala Coal-field, Salt-range, Punjab.

Part 2 (out of print).—Petroleum from Burma. Singareni Coal-field, Hyderabad (Deccan) Gohna Landslip, Garhwal.

Part 3 (out of print).—Cambrian Formation of Eastern Salt-range Giridih (Karharbari) Coal fields. Chipped (?) Flints in Upper Miocene of Burma. Velates Schmideliana, Chemn. and Provelates grandis, Sow. sp., in Tertiary Formation of India and Burma.

Part 4 (out of print).—Geology of Wuntho in Upper Burma. Echinoids from Upper Cretaceou[s] System of Baluchistan. Highly Phosphatic Mica Periodotites intrusive in Lower Gondwan[a] Rocks of Bengal. Mica-Hypersthene-Hornblende-Peridotite in Bengal.

Vol. XXVIII, 1895.

Part 1.—Annual report for 1894. Cretaceous Formation of Pondicherry. Early allusion t[o] Barren Island. Bibliography of Barren Island and Narcondam from 1884 to 1894.

Part 2 (out of print).—Cretaceous Rocks of Southern India and geographical conditions durin[g] later cretaceous times. Experimental Boring for Petroleum at Sukkur from October 189[3] to March 1895. Tertiary system in Burma.

Part 3 (out of print).—Jadeite and other rocks, from Tammaw in Upper Burma. Geology o[f] Tochi Valley. Lower Gondwanas in Argentina.

Part 4 (out of print).—Igneous Rocks of Giridih (Kurhurbaree) Coal-field and their Contac[t] Effects. Vindhyan system south of Sone and their relation to so-called Lower Vindhyan Lower Vindhyan area of Sone Valley. Tertiary system in Burma.

Vol. XXIX, 1896.

Part 1 (out of print).—Annual report for 1895. Acicular inclusions in Indian Garnets. Origi[n] and Growth of Garnets and of their Micropegmatitic intergrowths in Pyroxenic rocks.

Part 2 (out of print).—Ultra-basic rocks and derived minerals of Chalk (Magnesite) hills, and othe[r] localities near Salem, Madras. Corundum localities in [illegible]

Part 3.—Igneous Rocks from the Tochi Valley. Notes.

Part 4 (out of print).—Steatite mines, Minbu district, Burma. Lower Vindhyan (Sub-Kaimur) area of Sone Valley, Rewah. Notes.

Vol. XXX, 1897.

Part 1.—Annual report for 1896. Norite and associated Basic Dykes and Lava-flows in Southern India. Genus Vertebraria. On Glossopteris and Vertebraria.

Part 2.—Cretaceous Deposits of Pondicherri. Notes.

Part 3 (out of print).—Flow structure in igneous dyke. Olivine-norite dykes at Coonoor. Excavations for corundum near Palakod, Salem District. Occurrence of coal at Palana in Bikaner. Geological specimens collected by Afghan-Baluch Boundary Commission of 1896.

Part 4.—Nemalite from Afghanistan. Quartz-barytes rock in Salem district, Madras Presidency. Worn femur of Hippopotamus irravadicus, Caut. and Falc., from Lower Pliocene of Burma. Supposed coal at Jaintia, Baxa Duars. Percussion Figures on micas. Notes.

Vol. XXXI, 1904.

Part 1 (out of print).—Prefatory Notice. Copper-ore near Komai, Darjeeling district. Zewan beds in Vihi district, Kashmir. Coal deposits of Isa Khel, Mianwali district, Punjab. Um-Rileng coal-beds, Assam. Sapphirine-bearing rock from Vizagapatam District. Miscellaneous Notes. Assays.

Part 2 (out of print).—Lt.-Genl. C. A. McMahon. Cyclobus Haydeni Diener. Auriferous Occurrences of Chota Nagpur, Bengal. On the feasibility of introducing modern methods of Coke-making at East Indian Railway Collieries, with supplementary note by Director, Geological Survey of India. Miscellaneous Notes.

Part 3 (out of print).—Upper Palæozoic formations of Eurasia. Glaciation and History of Sind Valley. Halorites in Trias of Baluchistan. Geology and Mineral Resources of Mayurbhanj. Miscellaneous Notes.

Part 4 (out of print).—Geology of Upper Assam. Auriferous Occurrences of Assam. Curious occurrence of Scapolite from Madras Presidency. Miscellaneous Notes. Index.

Vol. XXXII, 1905.

Part 1.—Review of Mineral production of India during 1898—1903.

Part 2 (out of print).—General report, April 1903 to December 1904. Geology of Provinces of Tsang and Ü in Tibet. Bauxite in India. Miscellaneous Notes.

Part 3 (out of print).—Anthracolithic Fauna from Subansiri Gorge, Assam. Elephas Antiquus (Namadicus) in Godavari Alluvium. Triassic Fauna of Tropites-Limestone of Byans. Amblygonite in Kashmir. Miscellaneous Notes.

Part 4.—Obituary notices of H. B. Medlicott and W. T. Blanford. Kangra Earthquake of 4th April 1905. Index to Volume XXXII.

Vol. XXXIII, 1906.

Part 1 (out of print).—Mineral Production of India during 1904. Pleistocene Movement in Indian Peninsula. Recent Changes in Course of Nam-tu River, Northern Shan States. Natural Bridge in Gokteik Gorge. Geology and Mineral Resources of Narnaul District (Patiala State). Miscellaneous Notes.

Part 2.—General report for 1905. Lashio Coal-field, Northern Shan States. Namma, Mansang and Man-se-le Coal-fields, Northern Shan States, Burma. Miscellaneous Notes.

Part 3 (out of print).—Petrology and Manganese-ore Deposits of Sausar Tahsil, Chhindwara district, Central Provinces. Geology of part of valley of Kanhan River in Nagpur and Chhindwara districts, Central Provinces. Manganite from Sandur Hills. Miscellaneous Notes.

Part 4 (out of print).—Composition and Quality of Indian Coals. Classification of the Vindhyan System. Geology of State of Panna with reference to the Diamond-bearing Deposits. Index to Volume XXXIII.

Vol. XXXIV, 1906.

Part 1.—Fossils from Halorites Limestone of Bambanag Cliff, Kumaon. Upper Triassic Fauna from Pishin District, Baluchistan. Geology of portion of Bhutan. Coal Occurrences in Foot-hills of Bhutan. Dandli Coal-field: Coal outcrops in Kotli Tehsil of Jammu State. Miscellaneous Notes.

Part 2 (out of print).—Mineral production of India during 1905. Nummulites Douvillei, with remarks on Zonal Distribution of Indian Nummulites. Auriferous Tracts in Southern India. Abandonment of Collieries at Warora, Central Provinces. Miscellaneous Notes.

Part 3.—Explosion Craters in Lower Chindwin District, Burma. Lavas of Pavagad Hill. Gibbsite with Manganese-ore from Talevadi, Belgaum district, and Gibbsite from Bhekowli, Satara District. Classification of Tertiary System in Sind with reference to Zonal distribution of Eocene Echinoidea.

Part 4 (out of print).—Jaipur and Nazira Coal-fields, Upper Assam. Makum Coal-fields between Tirap and Namdang Streams. Kobat Anticline, near Seiktein, Myingyan district, Upper Burma. Asymmetry of Yenangyat-Singu [illegible]

Vol. XXXV, 1907.

Part 1 (out of print).—General report for 1906. Orthophragmina and Lepidocyclina in Nummulitic Series. Meteoric Shower of 22nd October 1903 at Dokachi and neighbourhood, Dacca district.

Part 2.—Indian Aerolites. Brine-wells at Bawgyo, Northern Shan States. Gold-bearing Deposits of Loi Twang Shan States. Physa Prinsepii in Maestrichtian strata of Baluchistan. Miscellaneous Notes.

Part 3.—Preliminary survey of certain Glaciers in North-West Himalaya. A.—Notes on certain Glaciers in North-West Kashmir.

Part 4.—Preliminary survey of certain Glaciers in North-West Himalaya. B.—Notes on certain Glaciers in Lahaul. C.—Notes on certain Glaciers in Kumaon. Index to Volume XXXV.

Vol. XXXVI, 1907-08.

Part 1 (out of print).—Petrological Study of Rocks from hill tracts, Vizagapatam district, Madras Presidency. Nepheline Syenites from hill tracts, Vizagapatam district, Madras Presidency. Stratigraphical Position of Gangamopteris Beds of Kashmir. Volcanic outburst of Late Tertiary Age in South Hsenwi, N. Shan States. New suidæ from Bugti Hills, Baluchistan. Permo-Carboniferous Plants from Kashmir.

Part 2.—Mineral Production of India during 1906. Ammonites of Bagh Beds. Miscellaneous Notes.

Part 3 (out of print).—Marine fossils in Yenangyaung oil-field, Upper Burma. Freshwater shells of genus Batissa in Yenangyaung oil-field, Upper Burma. New Species of Dendrophyllia from Upper Miocene of Burma. Structure and age of Taungtha Hills, Myingyan district, Upper Burma. Fossils from Sedimentary rocks of Oman (Arabia). Rubies in Kachin hills, Upper Burma. Cretaceous Orbitoides of India. Two Calcutta Earthquakes of 1906. Miscellaneous Notes.

Part 4 (out of print).—Pseudo-Fucoids from Pab sandstones at Fort Munro, and from Vindhyan series. Jadeite in Kachin Hills, Upper Burma. Wetchok-Yedwet Pegu outcrop, Magwe district, Upper Burma. Group of Manganates, comprising Hollandite, Psilomelane and Coronadite. Occurrence of Wolfram in Nagpur district, Central Provinces. Miscellaneous Notes. Index to Volume XXXVI.

Vol. XXXVII, 1908-09.

Part 1 (out of print).—General report for 1907. Mineral Production of India during 1907. Occurrence of striated boulders in Blaini formation of Simla. Miscellaneous Notes.

Part 2.—Tertiary and Post-Tertiary Freshwater Deposits of Baluchistan and Sind. Geology and Mineral Resources of Rajpipla State. Suitability of sands in Rajmahal Hills for glass manufacture. Three new Manganese-bearing minerals:—Vredenburgite, Sitaparite and Juddite. Laterites from Central Provinces. Miscellaneous Notes.

Part 3 (out of print).—Southern part of Gwegyo Hills, including Payagyigon-Ngashandaung Oil-field. Silver-lead mines of Bawdwin, Northern Shan States. Mud volcanoes of Arakan Coast, Burma.

Part 4.—Gypsum Deposits in Hamirpur district, United Provinces. Gondwanas and related marine sedimentary system of Kashmir. Miscellaneous Notes. Index to Volume XXXVII.

Vol. XXXVIII, 1909-10.

Part 1.—General report for 1908. Mineral Production of India during 1908.

Part 2 (out of print).—Ostrea latimarginata in "Yenangyaung stage" of Burma. China-clay and Fire-clay deposits in Rajmahal Hills. Coal at Gilhurria in Rajmahal hills. Pegu Inlier at Ondwe, Magwe district, Upper Burma. Salt Deposits of Rajputana. Miscellaneous Notes.

Part 3.—Geology of Sarawan, Jhalawan, Mekran and the State of Las Bela. Hippurite-bearing Limestone in Seistan and Geology of adjoining region. Fusulinidæ from Afghanistan. Miscellaneous Notes.

Part 4.—Geology and Prospects of Oil in Western Prome and Kama, Lower Burma (including Namayan, Padaung, Taungbogyi and Ziaing). Recorrelation of Pegu system in Burma with notes on Horizon of Oil-bearing Strata (including Geology of Padaukpin, Banbyin and Aukmanein). Fossil Fish Teeth from Pegu system, Burma. Northern part of Yenangyat Oil-field. Iron Ores of Chanda, Central Provinces. Geology of Aden Hinterland. Petrological Notes on rocks near Aden. Upper Jurassic Fossils near Aden. Miscellaneous Notes. Index to Volume XXXVIII.

Vol. XXXIX, 1910.

Quinquennial Review of Mineral Production of India during 1904 to 1908.

Vol. XL, 1910.

Part 1.—Pre-Carboniferous Life-Provinces. Lakes of Salt Range in the Punjab. Preliminary survey of certain Glaciers in Himalaya. D.—Notes on certain glaciers in Sikkim. New Mammalian Genera and Species from Tertiaries of India.

Part 2 (out of print).—General Report for 1909. Mineral Production of India during 1909.
Part 3.—Revised Classification of Tertiary Freshwater Deposits of India. Revision of Silurian Trias Sequence in Kashmir. Fenestella-bearing beds in Kashmir.
Part 4.—Alum Shale and Alum Manufacture, Kalabagh, Mianwali district, Punjab. Coal-fields in North-Eastern Assam. Sedimentary Deposition of Oil. Miscellaneous Notes. Index to Volume XL.

VOL. XLI, 1911-12.

Part 1.—Age and continuation in Depth of Manganese-ores of Nagpur-Balaghat Area, Central Provinces. Manganese-ore deposits of Gangpur State, Bengal, and Distribution of Gondite Series in India. Baluchistan Earthquake of 21st October 1909. Identity of Ostrea Promensis, Noetling, from Pegu System of Burma and Ostrea Digitalina, Eichwald, from Miocene of Europe. Mr. T. R. Blyth. Miscellaneous Notes.
Part 2.—General Report for 1910. Devonian Fossils from Chitral, Persia, Afghanistan and Himalayas. Sections in Pir Panjal Range and Sind Valley, Kashmir.
Part 3.—Mineral Production of India during 1910. Samarskite and other minerals in Nellore District, Madras Presidency. Coal in Namchik Valley, Upper Assam. Miscellaneous Notes.
Part 4.—Pegu-Eocene Succession in Minbu District near Ngape. Geology of Henzada District, Burma. Geology of Lonar Lake, with note on Lonar Soda Deposit. International Geological Congress of Stockholm. Miscellaneous Notes. Index to Volume XLI.

VOL. XLII, 1912.

Part 1.—Survival of Miocene Oyster in Recent Seas. Silurian Fossils from Kashmir. Blödite from Salt Range. Gold-bearing Deposits of Mong Long, Hsipaw State, Northern Shan States, Burma. Steatite Deposits, Idar State. Miscellaneous Note.
Part 2.—General Report for 1911. Dicotyledonous Leaves from Coal Measures of Assam. Poting Glacier, Kumaon, Himalaya, June 1911. Miscellaneous Notes.
Part 3.—Mineral Production of India during 1911. Kodurite Series.
Part 4.—Geological Reconnaissance through Dehong Valley, being Geological Results of Abor Expedition, 1911-12. Traverse Across the Naga Hills of Assam. Indian Aerolites. Miscellaneous Notes.

VOL. XLIII, 1913.

Part 1 (out of print).—General Report for 1912. Garnet as a Geological Barometer. Wolframite in Tavoy District, Lower Burma. Miscellaneous Notes.
Part 2 (out of print).—Mineral Production of India during 1912. Relationship of the Himalaya to the Indo-Gangetic Plain and the Indian Peninsula. Hambergite from Kashmir.
Part 3.—Contributions to the geology of the Province of Yünnan in Western China: I.—Bhamo-Têng Yüeh Area. II.—Petrology of Volcanic Rocks of Têng-Yüeh District. The Kirna Hills. Banswal Aerolite.
Part 4.—Gold-bearing Alluvium of Chindwin River and Tributaries. Correlation of Siwalik with Mammal Horizons of Europe. Contributions to the Geology of the Province of Yünnan in Western China: III.—Stratigraphy of Ordovician and Silurian Beds of Western Yünnan, with Provisional Palæontological Determinations. Notes on "Camarcorinus Asiaticus" from Burma.

VOL. XLIV, 1914.

Part 1. General Report for 1913. Carbonaceous Aërolite from Rajputana. Nummulite as Zone Fossils, with description of some Burmese species.
Part 2.—Contributions to the Geology of the Province of Yünnan in Western China: IV.—Country around Yünnan Fu. Dyke of white Trap from Pench Valley Coal-field, Chhindwara District, Central Provinces. Mineral concessions during 1913.
Part 3.—Coal-seams near Yaw River, Pakokku District, Upper Burma. The Monazite Sands of Travancore. Lower Cretaceous Fauna from Himalayan Gieumal Sandstone together with description of a few fossils from Chikkim series. Indarctos salmontanus Pilgrim. Future Beheading of Son and Rer Rivers by Hasdo.
Part 4.—Salt Deposits of Cis-Indus Salt Range. Teeth referable to Lower Siwalik Creodont genus 'Dissopsalis' Pilgrim. Glaciers of Dhauli and Lissar Valleys, Kumaon, Himalaya, September 1912. Miscellaneous Notes.

VOL. XLV, 1915.

Part 1.—New Siwalik Primates. Brachiopoda of Namyau Beds of Burma. Miscellaneous Note.
Part 2.—General Report for 1914. Note on Sivaelurus and Paramachaerodus.
Part 3.—Mineral Production of India during 1914. Three New Indian Meteorites. Kuttippuram, Shupiyan and Kamsagar. Dentition of Tragulid Genus Dorcabune. Hematite Crystals of Corundiform Habit from Kajlidongri, Central India.
Part 4.—Geology of country near Ngahlaingdwin

Vol. XLVI, 1915.

Quinquennial Review of Mineral Production of India for 1909 to 1913.

Vol. XLVII, 1916.

Part 1.—General Report for 1915. Eocene Mammals from Burma. Miscellaneous Notes.

Part 2.—The Deccan Trap Flows of Linga, Chhindwara District, Central Provinces. Iron Ore Deposits of Twinngé, Northern Shan States.

Part 3.—Obituary: R. C. Burton. Mineral Production of India during 1915. Flemingostrea, an eastern group of Upper Cretaceous and Eocene Ostreidæ, with descriptions of two new species.

Part 4.—Contributions to the Geology of the Province of Yünnan in Western China: 5.—Geology of parts of the Salween and Mekong Valleys. A fossil wood from Burma. The Visuni and Ekh Khera Aerolites.

Vol. XLVIII, 1917.

Part 1.—General Report for 1916. A revised classification of the Gondwana System.

Part 2.—Mineral Production of India during 1916. Mammal collections from Basal Beds of Siwaliks.

Part 3.—Crystallography and Nomenclature of Hollandite. Geology and Ore Deposits of Bawdwin Mines. Miscellaneous Notes.

Part 4.—Biana-Lalsot Hills in Eastern Rajputana. Origin of the Laterite of Seoni, Central Provinces.

Vol. XLIX, 1918-19.

Part 1.—General Report for 1917. Cassiterite Deposits of Tavoy. Les Echinides des "Bagh Beds."

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Vol. L, 1919.

Part 1.—General Report for 1918. Potash Salts of Punjab Salt Range and Kohat. Origin and History of Rock-salt Deposits of Punjab and Kohat.

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Part 4 (out of print).—Pitchblende, Monazite and other minerals from Pichhli, Gaya district, Bihar and Orissa. Natural Gas in Bituminous Salt from Kohat. Mineral Resources of Central Provinces. Miscellaneous Notes.

Vol. LI, 1920-21.

Part 1.—General Report for 1919. Pseudo-crystals of Graphite from Travancore. Mineral related to Xenotime from Manbhum District, Bihar and Orissa Province. Coal Seams of Foot-Hills of the Arakan Yoma, between Letpan Yaw in Pakokku and Ngapè in Minbu, Upper Burma. Observations on "Physa Prinsepii," Sowerby and on a Clionid Sponge that burrowed in its shell.

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Part 3.—Mineral Production of India during 1919. Results of a Revision of Dr. Noetling's Second Monograph on the Tertiary Fauna of Burma. Marine Fossils collected by Mr. Pinfold in the Garo Hills.

Part 4.—Illustrated comparative Diagnoses of Fossil Terebridæ from Burma. Indian Fossil Viviparæ. New fossil Unionid from the Intertrappean beds of Peninsular India. Unionidæ from the Miocene of Burma.

Vol. LII, 1921.

Quinquennial Review of Mineral Production of India for 1914—1918.

Vol. LIII, 1921.

Part 1.—General Report for 1920. Antimony deposit of Thabyu, Amherst district. Antimony deposits of Southern Shan States. Geology and Mineral Resources of Eastern Persia. Miscellaneous Notes.

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Part 4.—Stratigraphy of the Singu-Yenangyat Area. Analysis of Singu Fauna. Sulphur Deposits of Southern Persia. A Zone-Fossil from Burma: Ampullina (Megatylotus) Birmanica.

VOL. LIV, 1922.

Part 1.—General Report for 1921. Contributions to the Geology of the Province of Yünnan in Western China: 6.—Traverses between Tali Fu and Yunnan Fu. Geology of Takki Zam Valley, and Kaniguram-Makin Area, Waziristan. Geology of Thayetmyo and neighbourhood, including Padaukbin. Bitumen in Bombay Island.

Part 2.—Mineral Production of India during 1921. Iron Ores of Singhbhum and Orissa. Geological Results of Mount Everest Reconnaissance Expedition. Northern Extension of Wolfram-bearing Zone in Burma. Miscellaneous Note.

Part 3.—Obituary: Rupert William Palmer. Indian Tertiary Gastropoda, IV.—Olividæ, Harpidæ, Marginellidæ, Volutidæ and Mitridæ, with comparative diagnoses of new species, Structure of Cuticle in Glossopteris angustifolia Brongn. Revision of some Fossil Balanomorph Barnacles from India and the East Indian Archipelago. Contributions to the Geology of the Province of Yunnan in Western China: 7.—Reconnaissance Surveys between Shunning Fu, Chingtung Ting and Tali Fu. 8.—Traverse down Yang-tze-chiang Valley from Chin-chiang-kai to Hui-li-Chou. Boulder Beds beneath Utatur State, Trichinopoly District. Miscellaneous Notes.

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VOL. LV, 1923-24.

Part 1.—General Report for 1922. Indian Tertiary Gastropoda, No. 5, Fusidæ, Turbinellidæ, Chrysodomidæ, Strepturidæ. Buccinidæ, Nassidæ, Columbellidæ, with short diagnoses of new species. Geological Interpretation of some Recent Geodetic Investigations (being second Appendix to the Memoir on the structure of the Himalayas and of the Gangetic Plain as elucidated by Geodetic Observations in India).

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VOL. LVI, 1924-25.

Part 1.—General Report for 1923. Mineral Deposits of Burma.

Part 2.—Mineral Production of India during 1923. Soda rocks of Rajputana.

Part 3.—Gyrolite and Okenite from Bombay. Freshwater Fish from oil-measures of Dawna Hills. Fossil Ampullariid from Poonch, Kashmir. Calcareous Alga belonging to Triploporelleæ (Dasycladaceæ) from Tertiary of India. Froth Flotation of Indian Coals. Submarine Mud Eruptions off Arakan Coast, Burma. Cretaceous Fossils from Afghanistan and Khorasan.

Part 4.—Merua Meteorite. Stegodon Ganesa in Outer Siwaliks of Jammu. Land and Freshwater Fossil Molluscs from Karewas of Kashmir. Burmese Lignites from Namma, Lashio and Pauk. Maurypur Salt Works.

VOL. LVII, 1925.

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Part 1.—General Report for 1924. Fossil Tree in Panchet Series of Lower Gondwanas near Asansol, with Palæontological Description.

Part 2.—Obituary: Francis William Walker. Possibilities of finding concealed coal-field at a workable depth in Bombay Presidency. Basaltic Lavas penetrated by deep boring for coal at Bhusawal, Bombay Presidency.

Part 3.—Mineral Production of India during 1924. Enstatite-Augite Series of Pyroxenes. Constitution of the Glauconite and Celadonite. Palagonite-bearing Dolerite from Nagpur.

Part 4.—Fossiles Crétacés de l'Afghanistan. Fossiles du Kashmir et des Pamirs. Additions and Corrections to Vredenburg's Classification of the Cypræidæ. Petrology of Rocks from Girnar and Osham Hills, Kathiawar, India.

Vol. LIX, 1926.

Part 1.—General Report for 1925. Foraminifera of parts of Western India.
Part 2.—Sampling Operations in Pench Valley Coal-field. Composition of some Indian Garnets. Geology of Andaman and Nicobar Islands, with special reference to Middle Andaman Island. Occurrence of Cryptohalite. Remarks on Carter's Genus Conulites.
Part 3.—Mineral Production of India during 1925. Metamorphic Rocks and Intrusive Granite of Chhota Udepur State. Indian Species of Conoclypeus.
Part 4.—Low-Phosphorus Coking Coal in Giridih Coal-field. Distribution of Gault in India. Age of so-called Danian Fauna from Tibet. Bauxite on Korlapat Hill, Kalahandi State, Bihar and Orissa.

Vol. LX, 1927-28.

Part 1.—General Report for 1926. Six Recent Indian Aerolites.
Part 2.—Gas Eruption on Ramri Island, off Aracan Coast of Burma, in July, 1926. Oil Indications at Drigh Road near Karachi. Lower Canine of Tetraconodon. Geology of Bundi State, Rajputana.
Part 3.—Mineral Production of India during 1926. Geological Traverse in Yunaslin Valley. Ambala Boring of 1926-27 Indian Unfonidæ.
Part 4.—Relationship between Specific Gravity and Ash Contents of Coals of Korea and Bokaro Coals as Colloid Systems. Contact of Basalt with coal-seam in the Isle of Skye, Scotland. Comparison with Indian examples. Barakar-Ironstone Boundary near Begunia, Raniganj Coal-field. Raniganj-Panchet Boundary near Asansol, Raniganj Coal-field. Permo-Carboniferous Marine Fauna from Umaria Coal-field. Geology of Umaria Coal-field, Rewah State, Central India. Composition and Nomenclature of Chlorophæite and Palagonite, and on Chlorophæite Series. Miscellaneous Notes.

Vol. LXI, 1928-29.

Part 1.—General Report for 1927 Actinodon risinensis in Lower Gondwanas of Vihi district, Kashmir. Miscellaneous Note: Further Note on Nomenclature of Hollandite.
Part 2.—Contribution to Geology of Punjab Salt Range. Iron Ore Deposits of Northern Shan States. Lower Canine of Indian Species of Conohyus. Miscellaneous Note: Leucopyrite from Kodarma.
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Vol. LXII, 1929-30.

Part 1.—General Report for 1928. Miscellaneous Note: New Chromite Localities.
Part 2.—Obituary: Sivarau Sethu Rama Rau. Specific Gravity and Proximate Composition of Indian Vitrains. New Devonian Fossils from Burma. Rangoon Earthquakes of September and December 1927. Epicentre of North-West Himalayan Earthquake of 1st February 1929. Miscellaneous Notes: Indian Beryl, Atacamite in Bihar and Pyromorphite in Bhagalpur district, Bihar.
Part 3.—Mineral Production of India during 1928. Granophyric Trachyte from Salsette Island, Bombay. Coal Resources of Jharia Coal-field. Coal lost by Fires and Collapses in Indian Coal Mines.
Part 4.—Age of Aravalli Range. Lake's Rule for Angle of Overthrust, as applied to Himalayas. Permo-Carboniferous Succession in Warcha Valley, Western Salt Range, Punjab. Naoki (Hyderabad) Meteoric Shower of 29th September 1928. Miscellaneous Notes: Boring for water at Daryapur and Fossil Eggs at Yenangyoung.

Vol. LXIII, 1930.

Part 1.—General Report for 1929. Upper Triassic Fossils from Burmo-Siamese Frontier.—Thaungyin Trias and Description of Corals. Upper Triassic Fossils from Burmo-Siamese Frontier.—Brachiopoda and Lamellibranchia from Thaungyin River. Upper Triassic Fossils from Burmo-Siamese Frontier.—Fossils from Kamawkala Limestone. Upper Triassic Fossils from Burmo-Siamese Frontier.—New Dasycladacea, *Holosporella siamensis* nov. gen., nov. sp., with Description of Allied Genus *Aciculella* Pia. Cretaceous Cephalopods in 'Red Beds' of Kalaw, Southern Shan States, Burma.
Part 2.—Methods of Analysis of Coal used at Government Test House, Alipore, Calcutta, with an Editorial Introduction. New fossil localities within Panchet series of Raniganj Coal-field. Species of *Cyllene* from Pegu Beds of Burma. Two New species of *Unio*. Glaciers of Karakoram and Neighbourhood. Miscellaneous Note: Dome near Mari in Attock District.

Part 4.—Aspects of Modern Oil Field Practice. Undescribed freshwater Molluscs from various parts of India and Burma. Second note on North-West Himalayan Earthquake of 1st February, 1929. Miscellaneous Notes: Tremolite from near Jasidih, Bihar, Sapphirine in Vizagapatam District and Titaniferous Augite from Chandrawati, Sirohi State, Rajputana.

VOL. LXIV, 1930.

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VOL. LXV, 1931-32.

Part 1.—General Report for 1930. Additional Note on Samelia Meteorite. Zoning and Difference in Composition of Twinned Plagioclase Felspars in certain rocks from Sirohi State, Rajputana. Albite-Ala B Twinning of Plagioclase Felspars in certain acidic rocks from Sirohi State, Rajputana. Jurassic Fossils from Northern Shan States.

Part 2.—Syntaxis of North-West Himalayas: Its Rocks, Tectonics and Orogeny. Preliminary Note on Pegu Earthquake of May 5th, 1930. Determination from World Records of Zero-time and Epicentre of Pegu Earthquake of May 5th, 1930. Long Distance Wave Speeds of Pegu Earthquake of May 5th, 1930. Rocks bearing Kyanite and Sillimanite in Bhandara District, C. P. Stratigraphy of Upper Ranikot Series (Lower Eocene) of Sind, India. Miscellaneous Note: Fuchsite Vase from Mohenjo Daro (Sind).

Part 3.—Mineral Production of India during 1930. Geology and Lead-ore Deposits of Mawson, Federated Shan States. Weathering of Vindhyan Building Stone. *Maclurites* from Ordovician of Burma. Miscellaneous Notes: Supplementary note on "Revisions of Indian Fossil Plants, Part II Coniferales (b. Petrifactions), 1931" and Eruption of Mud Volcano off Arakan Coast.

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VOL. LXVI, 1932-33.

Part 1.—General Report for 1931. Rudistae from Eastern Persia.

Part 2.—Lower Palaeozoic Fossils from the Southern Shan States. Geology of Nanga Parbat (Mt. Diamir) and adjoining portions of Chilas, Gilgit District, Kashmir. Fossil Plants from Parsora Stage, Rewa. Swa Earthquake of August 8th, 1929. Overlap in the Ngape Area, Minbu District. Miscellaneous Note: Ammonite from Ramri Island.

Part 3.—Mineral Production of India during 1931. Microscopic Study of some Indian Coals. Specific Gravity and Porosity of Indian Building Stones. Study of Indian Seismological Records of Chief Shocks in North-East Frontier Region of Burma during 1929-1930. Glacier in Arwa Valley, British Garhwal.

Part 4.—Stratigraphic significance of Fusulinids of Lower Productus Limestone of Salt Range. *Dadoxylon zalesskyi*, new species of Cordaitean Trees from Lower Gondwanas of India. Fossil pentalocular fruit from Pondicherry. Kalava (Calwa) wall in Kurnool District. Talc-serpentine-chlorite-rocks of Southern Mewar and Dungarpur. Age of certain Himalayan Granites. Tables of Production, Imports, Exports and Consumption of Minerals and Metals in India.

VOL. LXVII, 1933-34.

Part 1.—General Report for 1932. Anthracolithic Faunas of Southern Shan States.

Part 2.—Geological Reconnaissance in the Southern Shan States. Geology of the country between Kalaw and Taunggyi, Southern Shan States.

Part 3.—Mineral Production of India during 1932. Geological Notes on Traverses in Tibet made by Sir Henry Hayden in 1922. Origin of Streaky Gneisses of Nagpur District.

Part 4.—Geology of the Krol Belt. Crush Conglomerates of Dharwar Age from Chota Nagpur and Jubbulpore.

VOL. LXVIII, 1934.

Part 1.—General Report for 1933. Obituary: Malhari Vinayak Rao. Khanpur Meteoric Shower. Cambrian Sequence of Punjab Salt Range.

Part 2.—Cambrian-Trias Sequence of North Western Kashmir (Parts of Muzaffarabad and Baramula Districts). Preliminary account of Earthquake of 15th January, 1934, in Bihar and Nepal. Obituary: Pramatha Nath Bose. Miscellaneous Notes: Barytes in Manbhum District, Bihar, Soda Deposit and Manufacture of Caustic Soda and Crude Soap at Parantij, Ahmedabad District, Potash-content of *Reshta*, Sambhar Salt Lake, Rajputana, Alunogen from Cuddapah District, and Quarterly Statistics of Production of Coal, Gold and Petroleum in India: January to March, 1934.

Part 3.—Mineral Production of India during 1933. Manganese-Lime Series of Garnets. Chemical Composition of Deccan Trap Flows of Linga, Chhindwara District, Central Provinces. Miscellaneous Note: Quarterly Statistics of Production of Coal, Gold and Petroleum in India: April to June, 1934.

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RECORDS

OF

THE GEOLOGICAL SURVEY OF INDIA.

Part 4.] 1934 [February

THE GEOLOGY OF THE KROL BELT.

BY J. B. AUDEN, M.A. (CANTAB.), *Assistant Superintendent, Geological Survey of India.* (With Plates 17 to 25.)

CONTENTS.

I. INTRODUCTION.

Situation.

The area described in this paper forms a small portion of the lower Himalaya between the Gambhar river, which flows from Simla to join the Sutlej, and the Jumna river, which forms a boundary between Chakrata tahsil and Tehri-Garhwal State.

It lies in the following territories:—Bharauli and Baghat divisions of the Simla Hill States, Patiala State, Sirmur (Nahan) State, and Chakrata tahsil of Dehra Dun district.

The part included in the map (Plate 25) is bounded by latitudes 30° 30′ and 31° and longitudes 77° and 78°. The term *Krol Belt* is taken from Krol Hill, 7,393 feet in height (30° 57′ : 77° 06′), which forms a conspicuous feature of the scenery between Kalka and Simla.

The Krol Belt occupies a narrow strip of mainly limestone country running N.W.-S.E. in its northern part, and changing in strike to nearly E.-W. towards the south.

The highest point is Juin Hill, 8,493 feet. The lowest point is by the Tons river near Kalsi, 1,530 feet. Most of the country lies below 4,500 feet. Two important rivers are the Blaini (Baliana)[1] and the Giri. Solon lies on the watershed between the Indus and the Ganges drainage systems.

Mapping.

The area was mapped during the hot-weather seasons of 1928, 1930, 1931 and 1932 and the cold weather of 1933. It is included in one inch to the mile sheets 53 F/1, 2, 5, 6, 10, and 14. Mapping in the Punjab was carried on almost entirely on the now obsolete two inches to the mile Punjab Forest sheets Nos. 312 N.W., S.W., N.E., S.E.; 313 N.E., S.E.; 335 N.W., S.W., N.E. The delineation of topography on these two-inch maps is for the most part astonishingly accurate. The modern one-inch maps are more generalised. Sheets 53 F/6 and 53 F/10 do not coincide properly at their common margin, and geological boundaries at the junction of these two sheets have been slightly adjusted. The whole of the mapping was subsequently reduced to the half-inch to the mile scale.

Scenery.

Except for Krol and Sainbar Hills, the greater part of the country between Subathu and Dadahu is devoid of character. Form is seldom seen, most of the hills showing only irregular masses of limestone interrupting the sky-line. E.N.E. of Dadahu a marked change occurs, due largely to the presence of the Tal rocks, which have a sobering effect on the underlying Krol limestones. Views of Guma, 8,098 feet, peak from Nigali Dhar (Plate 18), or of the great semicircle of limestones enclosing Tal rocks at Mishwa, yield examples of true mountain architecture.

[1] The spelling on the modern maps is *Baliana*. The term *Blaini* has become so fixed in Indian geological nomenclature that it should not be altered. It was written *Blini* by Medlicott.

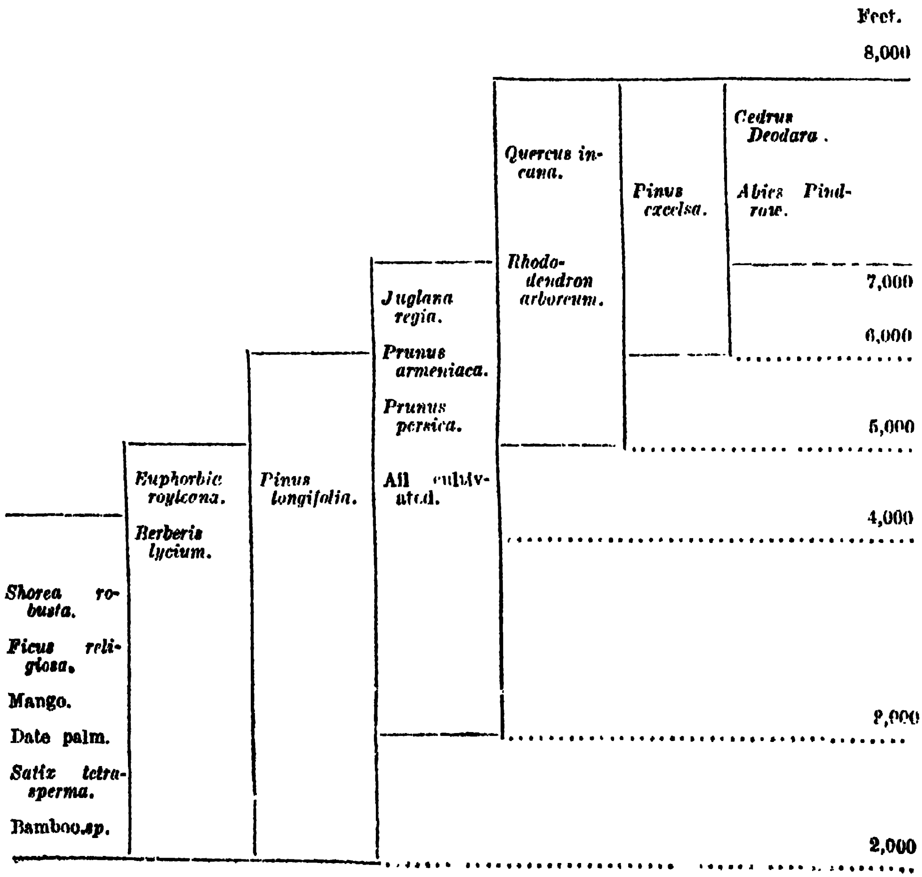
Climate.

Above 5,000 feet the temperature remains comfortably cool. Below 4,000 feet, during the months of April, May and June, climatic conditions are tropical. At this time of year the densely jungle-covered river valleys are hot, humid and unpleasant.

Flora.

The flora of the plains persists up to 4,000 feet. The dominant tree of the lower Himalayan foothills, particularly on sandy and shaly soils, is the *chil* or *chir* pine, *Pinus longifolia*. Higher up comes the oak-rhododendron association. The cedars and firs are rarely seen along the Krol Belt, being found only on the northern slopes of Guma and Juin peaks. The following is a table of the prominent shrubs and trees, with approximate altitude limits, for the area visited.

Table of Trees and Shrubs, with approximate altitude limits of growth.



Acknowledgment.

The writer is particularly indebted to Mr. W. D. West, who introduced him to the geology of the Simla hills, and who, together with Mr. D. N. Wadia, has discussed many of the questions brought forward in this paper. To Col. Sir S. R. Christophers, F.R.S., Director of the Research Institute, Kasauli, he is grateful for hospitality and for information concerning the Tertiary rocks. Finally, the assistance given by His Highness the Maharaja of Nahan State, and by the Sirmur Durbar, should be recorded.

II. PREVIOUS WORKERS.

H. B. Medlicott.

The first authoritative work was that of H. B. Medlicott in 1864[1], who described a tract of the Himalaya, 230 miles in length and 7,000 square miles in area, between the Ravi and Ganges rivers. Medlicott's attention was confined principally to the Tertiary rocks, but his observations on the pre-Tertiary rocks have formed the basis of all later work.

Though dividing up these latter rocks into metamorphic and unmetamorphic, Medlicott tended to correlate together those showing different degrees of metamorphism. His classification was as follows :—

Sub-Himalayan series.

Upper	Sivalik	
Middle	Nahun	
Lower	Subathu	Kasaoli. Dugshai. Subathu.

Himalayan series.

1. Unmetamorphic.
   - Krol.
   - Infra Krol.
   - Blini.
   - Infra Blini.
2. Metamorphic.
   - Crystalline and sub-crystalline rocks.

While the Infra-Krol and Krol rocks on Krol Hill are practically unmetamorphosed, Medlicott considered that their equivalents at Simla were crystalline schists, tremolite-limestones and recrystallised quartzites.

[1] *Mem. Geol. Surv. Ind.*, III, (1864).

In spite of the great area he covered, the wealth and detail of observation are remarkable, and Medlicott's memoir will for all time remain a classic.

R. D. Oldham.

Between 1883 and 1888, R. D. Oldham published a series of papers in the *Records*[1], on the geology of the hills between Simla and Chakrata. He was concerned chiefly with the Blaini and Infra-Blaini rocks and his work showed the difficulties which confront any detailed examination of complicated mountain areas.

In his second paper (cited below), he suggests a glacial origin for the Blaini conglomerate, re-naming it a *boulder slate.* In his fourth paper, he assigns an Upper Palaeozoic age to these beds.

C. S. Middlemiss.

From 1885 onwards, C. S. Middlemiss mapped and described large areas of British Garhwal.[2] From the point of view of this present account, his second paper, on the physical geology of West British Garhwal, is the most significant, since that tract of country lies to the south-east of, and in strike continuation with, the Krol Belt. A new standard of accuracy in mapping was there introduced, and the possibility of great rock translations was foreshadowed. Middlemiss paid particular attention to metamorphic condition, noticing transitions between rocks of widely different metamorphic grade.

Middlemiss worked later in the Hazara area, many of the rocks and structures of which are probably equivalent to those of the Krol Belt.[3]

In 1888-1889, R. D. Oldham surveyed the country bordering on the then projected Kalka-Simla railway. His results were written up in manuscript form, but were never published. His mapping of the Tertiaries is of great accuracy, but he did not bring out the complexity of the pre-Tertiary rocks. He accepts the correlations of Medlicott.

In 1908, Sir Thomas Holland described a striated boulder from the Blaini beds at Simla, remarking that the find added weight to Oldham's supposition of a glacial origin. He suggested a Purana age for the Blaini.[4]

[1] *Rec. Geol. Surv. Ind.*, XVI, pp. 193-198, (1883); *op. cit.*, XX, pp. 143-153, (1887); *op. cit.*, pp. 155-161, (1887); *op. cit.*, XXI, pp. 130-143, (1888).

[2] *Rec. Geol. Surv. Ind.*, XVIII, pp. 73-77, (1885); *op. cit.*, XX, pp. 26-40, (1887); *op. cit.*, pp. 134-143, (1887); *op. cit.*, pp. 161-176, (1887); *op. cit.*, XXI, pp. 11-28, (1888). *Mem. Geol. Surv. Ind.*, XXIV, (1890).

[3] *Mem. Geol. Surv. Ind.*, XXVI, (1896).

[4] *Rec. Geol. Surv. Ind.*, XXXVII, pp. 129-135, (1908-09).

Between the years 1915 and 1918, Prof. H. C. Das-Gupta, of the Presidency College, Calcutta University, led parties of students on excursions in the Solon and Simla neighbourhood. Prof. Gupta published various papers on the age and correlations of the rocks in this area.[1]

Prof. H. C. Das-Gupta.

In 1925, G. E. Pilgrim and W. D. West initiated a detailed survey of the Simla Hills, using the excellent two-inch to one mile Punjab Forest maps.[2] Their area lies adjacent to and north-east of that described in the present paper. Their work was confined almost entirely to the more metamorphosed rocks. They realised that the apparent simplicity of the sections at Simla was probably deceptive, and, discarding the correlation of the rocks at Simla with those on Krol Hill, they suggested instead that a series of thrusts had brought rocks of different degrees of metamorphism to lie in abnormal juxtaposition. Their succession is as follows:—

G. E. Pilgrim and W. D. West.

Dagshai series	Lower Miocene
Subathu series	Middle Eocene to Upper Oligocene
Krol series	?
Krol sandstone	Lower Gondwana
Infra-Krol beds	Lower Gondwana
Blaini limestone	Lower Gondwana
Blaini conglomerate	Lower Gondwana
Simla series (Infra-Blaini)	Lower Palaeozoic
Jaunsar series	Purana
Chail series	Purana
Jutogh series	Archaean ?
Shali limestone and slates	Position uncertain.

The sequence of the Jutogh, Chail, Jaunsar and Simla series was according to metamorphic condition, the most metamorphosed being regarded as the oldest. Since these series occur in such a manner

[1] *Journ. As. Soc. Beng.*, N. S., XIV, p. clxxxv, (1918). *Journ. Dept. Sci.*, VIII, (1926), Calc. Univ. Press; *op. cit.*, X, (1929).
[2] *Mem. Geol. Surv. Ind.*, LIII, (1928).

that the most metamorphosed rocks lie at the top, the more altered series were regarded as being founded upon thrusts over those that are less altered, as follows :—

Ascending sequence ↑

Jutogh series.	
	Jutogh thrust.
Chail series.	
	Chail thrust.
Jaunsar series	
	Jaunsar thrust.
Autochthonous sequence of Simla slates to Krol rocks.	

The existence of thrusts was indicated, independently of metamorphic condition, by disappearance of rock divisions owing to overlap.

An Upper Carboniferous age was re-introduced for the Blaini beds.

D. N. Wadia.

In 1928, Mr. D. N. Wadia gave an account of the geology of Poonch State and adjacent portions of the Punjab. In this memoir[1] he shows the existence of extensive thrust planes, and of volcanic rocks in the Upper Carboniferous and Permian. Thrust-planes are still more emphasised in later papers by Wadia, particularly that on the Himalayan syntaxis.

Work has been continued in the Simla hills by Mr. West and myself, summaries appearing in the Director's *General Reports.*[2] The writer has published a Miscellaneous Note on the supposed occurrence of *Chonetes* in the Krol limestone and a short paper on the age of certain Himalayan granites.[3]

Nature of paper.

The present paper is a continuation of the work started by Pilgrim and West. Some of the views put forward here differ slightly from those previously expounded. Areas have been examined which had not been formerly visited, and from the study of which modified interpretations have arisen. In no sense can these present opinions be considered final. They are put forward for the purpose of crystallising out the information and deductions before the collected data becomes too unwieldy. In regions of such complexity, modification is bound to result from continued work and fuller knowledge, but the later work is only a growth from that which has preceded, and is dependent on it.

[1] *Mem. Geol. Surv. Ind.*, LI, Pt. 2, (1928). *Rec. Geol. Surv. Ind.*, LXV, p. 189, (1931).

[2] *Rec. Geol. Surv. Ind.*, LXII, pp. 164-168, (1929); *op. cit.*, LXV, pp. 125-132, (1931); *op. cit.*, LXVI, pp. 125-130, (1932).

[3] *Op. cit.*, LXV, pp. 534-536, (1931); *op. cit.*, LXVI, pp. 461-471, (1933).

III. SEQUENCE OF FORMATIONS IN SIMLA-CHAKRATA HILLS.

Stratigraphical sequence.

Age.	Solon neighbourhood.			Tons river neighbourhood.		
Miocene	Nahans (only at Kalka)			Nahans		
Lower Miocene	Kasauli Dagshai			Dagshai		
Oligocene Eocene	Subathu (Nummulitic)			Subathu (Nummulitic)		
				never in contact.		
? Cretaceous and Jurassic	*absent.*			Tal	Upper Tal	
					Lower Tal	
? Permo-Carboniferous	Krol series	Krol limestone	Krol E	Krol series	Krol limestone	Upper Krol limestone
			Krol D			
			Krol C			
			Krol B (Red Shales)			Red Shales
			Krol A			Lower Krol limestone
		Krol sandstone				
		Infra-Krol			Infra-Krol	
Upper Carboniferous	Blaini			Blaini		
? Devonian and Silurian	Jaunsar with possible Mandhali			Nagthat stage Chandpur stage Mandhali stage	Jaunsar series	
? Lower Palaeozoic and pre-Cambrian	Simla slates with Kakarhatti limestone			Deoban limestone Simla slates (Morar-Chakrata beds)		
Miocene [and older]	Dolerites					

IV. LITHOLOGY.

The lithological characters of the various rock divisions will now be described, irrespective of whether correlation will ultimately render some of them equivalent. Beginning with the base of the succession are the Simla slates.

Simla Slates.

The Simla slates occur typically on the spurs between Simla and the Sutlej river. In the Krol[1] Belt, they are seen in a stretch of country which runs from the Gambhar river, past Kandaghat and along the Ashmi-Giri rivers. They also occur in the vicinity of Subathu and Solon. After a long gap, they crop out again between Morar, Chakrata and the Jumna river, north of the Tons thrust.

The Simla slates are dark- and sombre-coloured, with grey-blue tints, and are made up of micaceous shales, bleaching shales and slates, pencil slates, clay-slates, occasional phyllites, sandstones and predominant graywackes. Except for fracture cleavage in some of the shale bands between the more massive graywackes, true oblique cleavage is never seen. Parting is parallel to the bedding planes. Bedding thickness varies from ten feet to half an inch, but is characteristically massive.

AREAL TYPES.

(a) North-east of the Krol thrust.

Chhaosa type.

The Chhaosa slates are similar to those found north of Simla. They occur in massive beds, two and more feet in thickness. Graywackes predominate over slates. The most characteristic feature of the Chhaosa slates is the occurrence of numerous beds containing pillow- and kidney-shaped concretions, up to 18 inches in length, of impure quartzite and clay-slate set in a clay-slate matrix. The difference in composition between the concretions and the matrix is often very small. Many of the pillow-concretions are too flat for their origin to be explained by rolling and concentric accretion on an inclined floor. Possibly earthquake shocks jolted partly consolidated material amongst overlying softer muds that had been just previously deposited. Wash-outs may be seen, as in the Ashmi river below Sunny. Current-bedding is common, especially in the more quartzitic rocks, and in the Gambhar river shows the beds to be uninverted.

This division generally occurs in cliffs. The base is not seen. Its visible thickness is 1,400 feet in the excellent exposure along the Gambhar river.

Domehr slates.

The Domehr slates are thin-bedded and consist of soft, green, micaceous silts, gritty slates, cindery and nodular micaceous sandstones. Ripple-marking is very common. There is a complete lack of metamorphism. This division succeeds the Chhaosa slates and has a minimum thickness along the Gambhar river of 1,200 feet. It has not been recognised east of Kandaghat.

(b) *South-west of Krol thrust.*

Between Subathu and Arki, the Simla slates are richer in puckered leafy phyllites, but they exhibit as well some massive quartzitic bands, finely ripple-marked shaly quartzites and green nodular micaceous siltstones.

Kakarhatti limestone.

The chief feature of these slates is the intercalation of the Kakarhatti limestone. This is pale grey, blue-grey and purple in colour. It is microcrystalline and sometimes oolitic, whence its pseudo-organic appearance. Chert is abundant, in crinkled thalloid patches more or less parallel to the bedding. The limestone has been strongly strained and has sometimes flowed. It is associated with soft, green, needle shales and bleaching slates. It has been traced by Dr. Pilgrim from Subathu to Arki and must continue for at least five miles further north.

Microscopical.

There is no hard and fast line between sandstones, graywackes and slates. The finer slates, of grain-size less than 0·02 mm, are too obscured by clay-paste and dirt for determination (21959). In less fine-grained rocks, authigenic quartz, chlorite and sericite may be seen. The grain-size of the sandstones seldom exceeds 1·0 mm, being usually about 0·25 mm. Detrital grains of phyllite, quartz, muscovite, plagioclase (19203), tourmaline (21961) occur in a matrix with authigenic quartz, chlorite and sericite. Chlorite is common, in minute rods and bundles set in quartz (19204), as film-envelopes to grains (19211), or in patches (19204). Secondary sericite may occur in laths up to 0·25 mm long. Carbonate is rare (19205).

Kakarhatti limestone.—Concentric rings of carbonate occur round cores of more crystalline carbonate. Interstitial between the ooliths is a matrix of carbonate, detrital quartz, plagioclase and white mica. Of interest is the intimate authigenic association of quartz and carbonate in the ooliths. Good prism sections of quartz, with rhombohedral terminations, may be seen showing euhedral boundaries adjacent to and penetrating the rings of carbonate. Inside this authigenic quartz are

granules of carbonate which either are unreplaced remnants or represent incipient crystallisation of carbonate simultaneously with quartz. Authigenic chlorite is also common with sharp boundaries and fresh appearance (21956, 21958).

Jaunsars.

The Jaunsars are provisionally regarded as comprising three stages, in apparent ascending order:—The Mandhali stage; the Chandpur stage; and the Nagthat stage. These stages were only properly differentiated after this report had been written.

(a) *Mandhalis* (*Lower Jaunsar*).

A discussion of this difficult group of rocks is postponed till a later section (page 419). Here I shall assume as Mandhalis those beds which apparently underlie the Chandpur stage (Middle Jaunsars), and overlie, by thrust junctions:—

(a) Nahans and possible Dagshais on the south side of the Jaunsar syncline;

(b) Simla slates, with or without Nummulitics, on the north side of the Jaunsar syncline.

The apparent succession on both sides of the syncline is more or less the same, and is given below.

South limb.	*North limb.*
dips north.	dips south.
Chandpur stage.	Chandpur stage.
White massive quartzite.	White massive quartzite or quartz-schist.
(g) Bansa limestone, sporadic.	Bansa limestone, very persistent.
(f) Slates and phyllites.	Slates and phyllites.
(e) Dhaira (30 33′: 77 50′) limestone. Locally graphite-schist.	Khambroli (30 38′: 77 50′) limestone. Locally graphite-slate.
(d) Boulder bed.	Boulder bed.
(c) Quartzites, grits and conglomerates.	Quartzites, grits and conglomerates.
(b) Kalsi limestone or marble.	Naraya (30 39½′: 77 50½′) limestone or marble.
(a) Kalsi quartzites and bleaching slates.	*absent.*
Krol thrust, dip north.	*Tons thrust,* dip south.
Nahans, possible Dagshais	Nummulitics, possible Dagshais, resting on Simla slates.

(*a*) The Kalsi quartzites and bleaching slates may be seen on the hill half a mile W.S.W. of Kalsi post office and on the lower slopes of the hill-sides east of the Amlawa *nala*. The quartzites are dull grey-white, and highly veined with quartz. The slates are only seen in a weathered condition, being bleached and stained with iron oxides.

(*b*) The Kalsi limestones are most easily seen near the foot-bridge over the Amlawa *nala*, half a mile north of Kalsi post office, and on the col between hills 6,925 and 6,658 feet, south of Kailana.

They are highly banded and interbedded with slate or phyllite. Colours are variable—grey-blue, green, purple and variegated purple-white all being seen. A sandy basis is rare. When unstressed, the limestones are microcrystalline, but stress has commonly led to the formation of fine-grained marbles, which are sometimes visibly crystalline. Specimens from the same locality may be unfolded or highly contorted.

A feature which has occasionally been noticed, as, for example, one mile E. S. E. of Mandharsu, is that the apparent bedding-planes of this limestone are in reality joint-planes, since the composition bands, which give the true bedding, may be seen to cut these planes at high angles.

(*c*) The overlying quartzites, grits and conglomerates may be well seen just upstream from the footbridge over the Amlawa *nala* on the banks of the Jumna river, by mile 33 along the Chakrata-Mussoorie mule-track and at Dagura. Conglomerates are rare, but pebble beds containing pebbles of vein-quartz and purple slate or phyllite are common. Colours are pale green, grey and purple. The rocks are strongly ripped with vein-quartz, and are generally sheared to give schistose quartzites, and pebble-schists. Chlorite is the chief mineral developed, which imparts the dominant pale green colour. These schistose quartzites often weather into soft rocks that belie their real metamorphic nature, a consequence possibly of the ease of water permeation along the incipient planes of schistosity. There results an anomalous feature in that the Nummulitic quartzites, found locally at Dabra close to the Mandhalis, are vitreous, and appear superficially to show greater metamorphism than the weathered Mandhali quartz-schists.

(*d*) The boulder bed occurs almost invariably above these pebbly quartzites and just below the Dhaira limestone. There may be other boulder beds, but it is impossible to tell to what extent folding and faulting may have displaced the original succession and

have resulted in duplication of some beds with elimination of others that were formerly adjacent.

The best localities for seeing these rocks are in the Jumna river 700 yards W.S.W. of Bias, in the Tons river near the thrust contact of Mandhalis with Simla slates, a quarter of a mile S.S.W. of hill 6,571 feet, and in a *nala* half a mile south-east of Makhta. The matrix is either slate, gritty slate or pure sandstone. Boulders and pebbles consist characteristically of limestone, dark slate, pale and dark sheared quartzites, and vein-quartz. Limestone fragments are invariably present in these rocks, in contrast to their rarety in the boulder bed of the Blaini. The limestones are either dark and microcrystalline, or marmorised to white, speckled, fine-grained marbles, similar to the marmorised type of the Kalsi limestone. Occasionally pink-weathering limestones are also seen. Together with these limestone fragments, there are very frequently found slivers of dark limestone that grew *in situ* in the rock. In the Tons river, these slivers may be seen to be up to 3 feet 6 inches in length. They are never over two inches thick. It is impossible to assume that such flat plates of limestone were deposited as fragments derived from erosion of pre-existing limestones, since they would have fractured in transport. Stress has certainly caused elongation of some of the fragments of limestone and quartzite, but the dimensions of these slivers are such that they cannot be accounted for solely by stress-elongation. Further, lenticles of sandstone of similar type to the limestone slivers, are also found grading insensibly into a sandstone matrix containing boulders. The whole aspect of these rocks is that of original lenticular deposition of primary and derived constituents.

Immediately below the Dhaira limestone is sometimes seen a graphite-schist or slate. The clearest exposures are in the Jumna river, 700 yards W.S.W. of Bias, where graphite-schist intervenes between boulder bed and limestone, and in the Shwala *nala,* 0·67 miles west of Maralhau, where there is an abrupt contact of graphite-slate containing lenticles of carbonate and the overlying limestone.

(c) The Dhaira limestone is made up of thinly interbedded, dark, microcrystalline limestone and dark pyritic slate. The limestone is often lenticular and may closely resemble the Lower Krol limestone. It differs from the latter, however, in its greater degree of interbanding with slate, in its markedly angular folds, and in its frequently sandy basis. This limestone may be seen on the south side of the

Jaunsar syncline at Pathna, north of Badhana, hill 3,993 feet, Dhaira, and in the Jumna river at Bias. On the north side of the Jaunsar syncline, it is to be seen between Ara and Khambrali, near Uproli, and south of Dagura.

(*f*) Between the Dhaira and Bansa limestones occur silvery black, sheeny phyllites and pale green, slightly talcose phyllites. These are best seen north of Udpalta.

(*g*) The Bansa limestone is very distinctive since it weathers to deep blue-black, granular surfaces, showing abundance of sand grains. On fracture the limestone is almost invariably eu-crystalline and blue in colour, though grey and purple colours are sometimes seen. The bedding is coarse, though the individual beds may be seen to be made up of many bands of slightly varying sand content. This sand content is far greater than that of the Dhaira and Kalsi limestones, from which the Bansa limestone is also distinguished by its more massive bedding.

On the north limb of the Jaunsar syncline, the Bansa limestone has been traced almost without interruption for 24 miles and has been an invaluable horizon. Along the southern limb of the syncline it is inconstant, though it occurs intermittently from just north of Chandni to a short distance east of the Kalsi-Chakrata motor road after which it is, for some reason, cut out.

Intimately connected with the Bansa limestone and often interbedded with it, is a pale quartzite or quartz-schist. This has been placed as the bottom member of the Chandpur stage, though the division should not be taken to imply any break in sedimentation.

(*b*) *Chandpur stage* (*Middle Jaunsar*).

The rocks of this stage form a distinctive outcrop from Chandpur, past Naga Tibba, Chorani, and extending eastwards to Nag Tibba in 53 J/N.W.

The most characteristic features of this stage are a highly banded association of quartzite and phyllite, and the presence of abundant green beds. As many as 24 bands of quartzite and phyllite may be seen in two centimetres. Although quartzite is really in excess of phyllite, the latter appears to predominate since it invariably adheres as thin films to the surfaces of the quartzite. The true ratio is seen in sections at right angles to the bedding. As a result of compression, this quartzite-phyllite association is generally thrown into striking crinkles and fold-puckers, which, together with the small-scale

banding, result in simulation of fossil wood. The puckers resemble ripple-marks, but are usually too regular and of too accentuated amplitude actually to be so. True ripple-marks do occur in the quartzite bands, which impart to the later deposited muds, now phyllite, the same relief, but in such cases the amplitude is in keeping with that of ripple-marks. Later compression may, of course, fold these sedimentation ripples into puckers.

The phyllites grade into sheeny schistose phyllites, which just lack a sufficient degree of metamorphism to be called true schists. Such schistose rocks are used as roofing material at Manogi, wrongly called Dikroli, in 53 J/N.W.

Besides this dominant quartzite-phyllite association, there are more massive current-bedded quartzites and an extensive series of chlorite-tuffs, slates and quartzites. These green rocks occur in distinctive homogeneous beds, showing strong polygonal jointing, and brown crusty weathering. Fracture is with a sonorous 'hammer' ring.

The majority of these rocks are metamorphosed tuffs, though occasionally amygdaloidal basic lavas are found as along the Mussoorie-Chakrata mule-path between miles 20 and 22. The differentiation in the field between tuff, lava and fine-grained intrusive rock (? contemporaneous with the volcanic material) is often very difficult. The coarser dolerites are, of course, readily recognisable.

There is no doubt about the pyroclastic and volcanic nature of the green rocks themselves. It is possible, however, that much of the so-called quartzite-phyllite association may also be tuffaceous. Many of the quartzitic bands under the microscope show little clastic quartz, but solely a fine-grained mosaic of quartz, sericite and chlorite, similar to that found in the undoubted tuffs. I am indebted to Dr. J. A. Dunn for drawing my attention to this possibility, and to references to photographs of the highly banded, recent, sub-aerial tuffs in New Zealand.[1]

The thickness of this stage near Chorani and Nagthat is at least 4,500 feet.

(c) *Nagthat stage (Upper Jaunsar).*

The Nagthat stage was only recognised as a separate group in 1933, after this paper had already been written. West of the Tons,

[1] *Bull. N. Z. Dept. Scientific and Industrial Research*, No. 32, (1932).

it was not differentiated by mapping from the underlying Chandpur stage, though it is undoubtedly represented by outcrops in the Tons river below Andra, and at Minal Bag.

In the present map it is well seen on Nagthat Hill and by Lakhwar, but the best development is to the east, in sheets 53 J/N.W. and J/S.W.

The characteristic rocks are sandstones, arkoses, quartzites, grits, conglomerates, clay-slates and phyllites showing purple and green colours. Some of the sandstones are pyritic, weathering to rusty bleaching crusts. The arenaceous rocks are strongly current-bedded and ripple-marked. The conglomerates contain pebbles of vein-quartz, often stained red or purple, purple and pale quartzites, purple and green slate or phyllite. They are typical of the Jaunsar conglomerates of the Simla area. Green tuffaceous sandstones are developed east of the area included in the map.

Boulder beds have been found in probable Nagthat beds in two places. One exposure is on the hill-side 0·4 miles N.N.W. of Hiyun; the other exposure is in the Tons river 0·7 miles south-west of Altau. In both localities, the boulder beds are associated with quartzites, slates and phyllites, while in the Tons locality, there are also dark micaceous slates of Infra-Krol type. No limestones were seen. The boulders are angular, and consist of dark slate and greenish quartzite, types common in the Jaunsars. The matrix is gritty. Other boulder beds occur in what is definitely the Nagthat stage, south of the Aglar river in sheet 53 J/3.

In the Newali *nala*, immediately to the north-east of Khadayat, are found green tuffaceous quartzites, some of which are agglomeratic, and resemble the gritty facies of the Blaini when relatively free from pebbles and boulders.

Great variation in metamorphic condition occurs. Some of the rocks are soft clay-slates and sandstones. Others are talcose phyllites and schistose quartzites.

The rocks of this stage appear in the north to lie conformably upon the Chandpur stage, often with a basal conglomerate (Nagthat Hill). Towards the south it is probable that they overlap the Chandpur stage with marked unconformity. The significance of this unconformity is not at present fully understood.

Microscopical.

When unaltered, the arenaceous rocks of the Jaunsars are generally more or less pure quartzites, with or without plagioclase and tourmaline. Grain-size

averages 0·50 mm. within limits, in the specimens examined, of 1·7 mm. and 0·20 mm. The feldspar is almost always plagioclase, near the albite end (21978, 21967). Tourmaline is generally common (21977, 21967). The cement is silica. Increase of strain may be seen by the following progressive symptoms :—

(1) Extensive strain shadows, (19196, 21967).

(2) Breaking up of the clastic grains by frittering along the margins and formation of sericite quartz mosaic continuous with the grains. Strain shadows marked (21966, 21978).

(3) Greater proportion of matrix formed by break-down of the grains. Marked frittering and straining (21963, 21977). Clastic structure discernible under low-power and in ordinary light.

(4) Grains isolated in a crush matrix of sericite and quartz, chlorite and quartz, or chlorite, sericite and quartz. The original rounded clastic grains have lost their original contours and become angular, with frittered edges intimately associated with the pulp matrix (21976, 19197, 21969, 21970). In the hand specimen, some of these quartzites are markedly schistose (44·103).

(5) Matrix more common than grains and clastic origin just discernible under low-power. No original edges to grains.

21972, 21973 } chlorite-sericite-quartz-schist

21964 chlorite-sericite-magnetite-quartz-schist.

Not all the matrix of some of these rocks is secondary in origin, formed by the break-down of grains. Some of it is primary, being the finer-grained clayey matrix that surrounded the grains of quartz and feldspar. It is difficult in cases of obvious reconstruction, in which break-down is manifest, to determine the proportion of primary and secondary matrix, since both yield a fine-grained mosaic of sericite chlorite and quartz.

The rocks of sections 4 and 5 could be confused with those in the Chails. Tourmaline and plagioclase do not necessarily occur in the same slice. The plagioclase does not necessarily give rise to sericite on crushing, since even in crushed rocks full of secondary sericite, the detrital plagioclase may be fresh (21978).

Similar features are seen in the phyllites, but the ratio of matrix to detrital grains is greater. False cleavage occurs, oblique to the fine bands of phyllite and phyllitic quartzite (21971).

The finer-grained, mottled, green-purple beds are difficult to examine. A very fine and intimate association of quartz, chlorite and sericite is just discernible, the individual chlorite laths being up to 0·05 mm. in length (21974).

The limestones are generally crowded with detrital quartz and very frequently plagioclase, microcline, and tourmaline (21982). In most of the slices, there has been corrosion of quartz by carbonate (21983). The grains of quartz have lost their smooth edges, and show in growths of small prisms of carbonate. Apart from the detrital quartz, there is a finer-grained interpenetration of authigenic quartz and carbonate (21980).

Blaini.

There are two typical rock-facies in the Blaini :—the boulder bed or tillite, and the limestone. These form the most unique and

striking rock association of the whole area. There is, however, no typical development of the Blaini, since no two exposures agree in character. The boulder bed may occur alone; or limestone may occur alone. There may be several boulder beds, with or without limestones. The boulder beds, and/or limestones, may lie on Simla slates, on Jaunsars, in beds of Jaunsar type, or in those of Infra-Krol type. This last manner of occurrence is particularly common in the Solan area. The slates of Infra-Krol type that are so intimately connected with the Blaini, should probably be mapped as Blaini. Since, however, the boulder beds and limestones often die out laterally along the strike, there has in many cases been embarrassment in distinguishing between Blaini and Infra-Krol slates that are lithologically identical, but, which, on account of this absence, are no longer separated in dip section. Consequently, those slates of Infra-Krol type that occur below the Blaini are mapped as Infra-Krol. Similarly, conglomerates of Jaunsar type associated with the Blaini are mapped as Jaunsar.

Boulder beds or tillites.

The tillites are described in plural, though it is uncertain in the present area to what extent repetition of boulder beds and limestones in dip sections is due to original sedimentary repetition, and to what extent to imbricate faulting. That there must have been locally more than one boulder bed is shown by the presence of water-rounded boulders of tillite itself in tillite (Plate 20, fig. 2).

The boulder beds are generally dark grey-brown in colour, and consist of angular, sub-angular and rounded boulders set in a fine-grained matrix. The matrix may be clayey or gritty. The quantity of boulders varies, they in some exposures being absent. The boulder-free matrix in such cases is often a greenish, hard quartzite full of closely packed polygonal joints, as at Lagasan and in the Damkri *nala*. The size of the boulders varies from three feet to that of very small pebbles. Their angularity is for the most part determined by the jointing and thin-bedding of the parent rocks from which they were eroded. There is gradation from tillite to conglomerate, containing rounded pebbles of vein-quartz. Good examples of this gradation may be seen in the *nala* which flows south from Kandon to join the Giri river. The boulder beds may be strongly sheared, in which case the matrix becomes cleaved, phyllitised and eventually schistose, while the pebbles become flattened out so as to be difficult to distinguish from the matrix. This is best seen on the Juint

Chandpur ridge. Scratches are sometimes found on the boulders, but it is impossible to be sure whether these are due to internal friction or to glacial action. Certain Jaunsar phyllites north of Shallai show the presence of grooves, which were at first taken to be due to internal friction, but which, on closer inspection under the lens, are found to be corrugations or minute cross-folds running perpendicular to the strike of the strain-slip cleavage.

The boulders and pebbles are of the following types:—dark slate, greenish quartzitic grit, pale quartzite, pepper sandstone, green siltstone or slate, banded slate, vein-quartz, occasional microcrystalline limestone weathering buff-coloured. Their provenance is undoubtedly the Simla slates and the Jaunsars. The provenance of the limestone fragments is uncertain. In one case the limestone appears to be of Blaini type (19194).

Limestone.

The limestone is generally pink and microcrystalline. It does not effervesce with acid or scratch with a knife. Its bedding is from half an inch to six inches and is generally contorted. Another type of limestone is one which is sandy and soft, weathering to thick dark orange-brown crusts. This is often distinctly ferruginous.

The limestone grades by addition of clay matter into calcareous shales and slates, which may be purple or pink in colour. Sometimes these are all that is seen in the Blaini, as at Barog Station, at the base of the Krol thrust.

Out of the great variety of sections seen in the Blaini rocks, the following three may be taken:—

(*a*) *In the Tons river, below Andra* (30° 36′ : 77° 44′)—

Infra-Krol slates with true cleavage.

Blaini boulder bed, 20 feet thick.

Jaunsar quartzites.

(*b*) *In the Kawal Khal, near height 3,241 feet* (30° 50′ : 77° 10′).

Infra-Krol banded clay-slate.

	Feet.
Purple and pink, banded, slaty limestone	50
More massive, pink, lenticular limestone	10
Highly sheared boulder bed, with twisted knots of gritty clay-slate	25
Finely banded green and purple crinkled slates	30
Typical boulder bed	25
Sheared slates and slaty quartzites	10
Conglomerate with 'eggs' of vein-quartz	15
	165

Banded and sheared bleaching slates, coloured on map as Infra Krol, but properly Blaini.

(c) *Dhar spur, near hill 4,960 feet* (30° 58′ : 77° 02′ 30″).

Infra-Krol shales and slates.	
Pink limestone	6
Boulder bed	6
Slates and gritty slates.	
Limestone	5
Boulder bed	5
Papery slates.	
Limestone	4
Boulder bed	4
Slates and gritty slates.	
Limestone	3
Boulder bed	3
Slates and gritty slates.	
Limestone (no boulder bed)	2
Leafy slates with gritty slates.	
Earthy limestone	1
Red shales	1
Pink limestone	1
Boulder bed	1

Horizontal distance of section, about 4,000 feet; dips variable, but minimum thickness 2,000 feet. Most of this is due probably to thrust multiplication (see Plate 25, Section 1).

Bleaching and papery slates, mapped as Infra-Krol. A small wedge of Subathus. The whole has been thrust over Subathus, by the Krol thrust.

Microscopical.

The matrix of the boulder bed shows angular fragments of quartz, quite ungraded, set in a dirty fine-grained quartz-clay matrix, with secondary sericite in laths of 0·016 mm. (22001). When the boulder beds are more crushed the sericite becomes longer, 0·03 mm. (22002). Exceptionally the matrix is of calcite or dolomite (21999), as in the outcrops of Blaini near Masria.

Pebbles include :—

Recrystallised mosaic quartzite (21999) . .	Probably Jutogh.
Sericite-quartzite (21999)	Probably Jutogh.
Fine-grained arkosic sandstone with ? glauconite (21999)	Simla slates.
Sandstone containing many grains of phyllite and carbonaceous slate (21998, 19195) .	Simla slates.
Grit with isotropic clay paste matrix, similar to grits below Blaini at Gadhasar (19193) .	Blaini.
Fine-grained sandy limestone (19194) . .	Blaini.

This list is not representative, since specimens for rock-sections were not taken from pebbles whose provenance was unquestionably Simla slate and Jaunsar. In particular this applies to the abundant boulders of dark slate so universally found in the Blaini.

The limestones do not call for comment. The typical hard siliceous limestone shows a very fine-grained mosaic of carbonate with interpenetrating quartz, and rare feldspar (19201). The impure sandy limestones show abundant quartz, with occasional oligoclase, detrital white mica, set in a matrix of carbonate (21997).

Infra-Krol.

The Infra-Krols are made up of highly incompetent rocks which have been so folded and inter-faulted that no representative section and no reliable estimate of their thickness can be made out. Fresh rocks of the Infra-Krols in stream sections differ so markedly from the more commonly seen weathered rocks on hill-sides that it has sometimes been difficult to assure oneself of their original identity.

The Infra-Krols consist chiefly of dark shales and slates, closely interbedded with thin buff-weathering a quarter of an inch to four-inch bands of impure slaty quartzite. This banding is close enough to be called of *varve* type. Occasionally thicker beds of pepper quartzite are found. Towards the top of the Infra-Krols (that is, in sections seen below the Krol sandstone and limestones), black carbonaceous shales or slates occur without the thin bands of slaty quartzite. The overlying of paler Krol sandstones on black Infra-Krols is well seen on the spurs south of Krol Hill and north-west of Rajgarh Hill. From a distance the dark carbonaceous beds shine in a striking manner in the reflected light of an afternoon sun.

The banded facies of dark shale and paler impure quartzite weathers on hill-sides to a very characteristic association of thin, bulbous, sheeny, gritty clay-slate, often green in colour, and concentric ring-bleached slates. The latter are ramified with irregular joints, now marked out by harder ridges as a result of liberation of iron and its precipitation as ferric hydroxide cement. On account of strong small-scale folding and recent cementation, these two rock types usually occur together in complete chaos. The commonness of iron in the Infra-Krols is seen in the universal seepages of ferric hydroxide, and white incrustations of ferric sulphate and chloride, which cover the surfaces of these rocks. The parent mineral must have been pyrites.

The Infra-Krols show great variation in the extent of metamorphism. In the Solan neighbourhood shales predominate, though at the closing end of the Krol syncline, in the lower Blaini river, the shales become true slates, with cleavage dip to the north-east. The intervening harder bands do not cleave. East of Dadahu the Infra-Krols are universally cleaved, while northwards, north of Soat and on Juin and Chandpur Hills, some of the beds turn into pearly phyllites and even become schistose. In these places they are ramified by veins of quartz. Their identification with the Infra-Krols is told by their occurrence between the Blaini and Lower Krol limestones,

which also show a concomitant increase in metamorphism, and is supported by the presence of ring-bleached slates of more normal Infra-Krol type. East of Dadahu cleavage varies in dip from 35° to 70°, and in dip direction from N. N. W. to N. N. E. The minimum thickness of the Infra-Krol rocks is about 500 feet, but no reliable estimate is possible.

Microscopical.

The cleaved slates consist of a poikiloblastic mixture of sericite and quartz with sericite up to 0·035 mm. in length. Pyrites is abundant (22005). The associated slaty quartzites, or gritty clay-slates, are frequently calcareous and show a reformed mass of quartz, carbonate, sericite, pyrites. Some of these tougher bands resemble the sandy limestone or calcareous sandstone facies of the Blaini (22004). Increase in alteration is told by the greater size of the sericite laths. Slice 22006 is a reformed mixture of chlorite, sericite and quartz, with considerable quantities of carbonate and pyrites. The chlorite and sericite may occur together in a single crystal in alternate layers parallel to the basal plane. In all these rocks, there is a large quantity of carbonaceous dirt.

Krol Sandstone.

In the Solon neighbourhood, the Krol sandstone is generally seen as a soft crumbling sandstone, without good bedding and stained an orange colour with iron. Excellent exposures are found along the Kalka-Simla motor road, at the foot of Pachmunda Hill and at Salogra. North of Krol Hill, near Kandaghat, and in the *nala* which flows from Solon to join the Giri river, the sandstone is a hard quartzite in which bedding is well displayed. A conspicuous feature is the presence of bands rich in disc-like fragments of black shale, seldom over 2 mm. thick but up to 5 cm. long. These shale fragments readily bleach, and are almost certainly derived from penecontemporaneous erosion of the underlying Infra-Krols. Towards the south-east the sandstone ceases to be a single horizon, but splits up and becomes strongly interbedded with carbonaceous shale. Such interbanding may be seen in the Kawal Khal and at Ajga. Still further to the south-east, the intervening shale bands tend to disappear and, besides the quartzites with shale discs, there are coarser lenticular pebbly beds. The sandstone is 350 feet thick on the south face of Krol

Hill above Baran, 50 feet in the south-east corner of sheet 53 F/1, two feet in the Giri river at Dadahu, and dies out on the western side of hill 3,619 feet.

In the tightly squeezed Krol syncline in the Kawal Khal, the sandstone becomes a horny quartzite, strongly veined with quartz. At Kadhar, below a local thrust, it has been highly polished by friction and has been broken down (22010).

Mr. Wadia[1] has suggested that some of the Krol sandstone may be a metasomatised limestone. The microscopical evidence is against this supposition, since it is difficult to see how any replacement of lime by silica would result in such a striking grain structure as is shown by these sandstones. Had there been replacement, one would have expected an irregular mosaic of quartz and chalcedony. The only mosaic that has been observed is that in the crushed rock from Kadhar, where there is no question as to its mode of origin. The crumbling variety of the sandstone may probably be explained by de-silicification, and loss of the silica cement.

Microscopical.

The most striking feature of the Krol sandstone in the neighbourhood of Solon is the degree of rounding of the grains. In very fine varieties, such as 19188, in which the maximum grain size is 0·15 mm., the grains are all angular. The remainder of the rock sections show excellent rounding in grains of 0·30 and 0·25 mm. in diameter. In two slices (19183, 19185), the rounding is well displayed in grains of 0·20 and 0·17 mm. diameter. There is generally a strong silica cement (19185, 19184).

In the sheared sandstone from Kadhar (22010) are seen veins of crushed rock which are now a recrystallised mosaic of quartz and from which the clastic structure has been quite lost. There are intense strain shadows, and an increase in birefringence of the chlorite envelopes to the grains. This crushing is local, since in the same slice may be seen less crushed grains, 0·20 mm. in diameter, in which the rounding has not been obliterated.

The rounding of the grains is almost certainly due to wind action, since 0·30 mm. appears to be the minimum possible diameter for rounding caused by attrition in water.[2]

[1] *Rec. Geol. Surv. Ind.*, LXV, p. 128, (1931).

[2] Bailey, *Geol. Mag.*, p. 105, (1924). Twenhofel, 'Treatise on Sedimentation', pp. 165-170, (1926), cites experiments by Galloway in which the lower effective limit of abrasion in water is considerably less than 0·30 mm., particularly for soft minerals. However, the percentage of well-rounded grains of hard quartz in the Krol sandstones is over 50, and the deduction given above is probably valid. The rounding was due to wind, but the sandstones were water-deposited.

Krol Limestones.

In this division of the Krol series is a great variety of limestones and shales. In the Solan area, Oldham divided the Krol limestones into three sub-stages :—

Upper Krol limestone,
Red Shales,
Lower Krol limestone.

Between longitudes 77° and 77° 25′, it has been found possible to subdivide the Upper Krol limestone into three sub-stages, so that in all five sub-stages have been mapped in order the better to bring out the structure of the belt. For the most part, differentiation has been relatively easy. In places, however, on account of a basic similarity shown by some of the limestones in the three upper sub-stages, and owing to the intense folding which the eye can see to have taken place, aside from what is evinced by the mapping itself, differentiation has been more uncertain. This applies chiefly to squares A 1 and B 1 in sheet 53 F/6. East of 77° 25′, the original three divisions made by Oldham in the Solon area have been adhered to, although locally, especially near Mishwa, it would have been possible to delineate all five. Here, however, no useful purpose would have been served by subdividing the Upper Krol limestone, since the overlying Tal beds have prevented the Krols folding individually. Tals, Krol limestones, Infra-Krols and Blaini fold as a single unit. The combined thickness of the Krol limestones varies from about 1,800 feet to nearly 4,000 feet.

Krol A (Lower Krol limestone).

In the area round Solon, this stage is made up of limestones and shales, in beds from one to four inches thick. Weathered surfaces show subdued grey-green tints. Fresh fractures are bluer. The limestones are seldom crystalline. In composition these beds show rapid alternations of shaly limestone and calcareous shale or slate; either in parallel beds (Plate 21, fig. 1), or as discontinuous, in-weathering, lenticular pillows of limestone surrounded by calcareous shale (some are seen in Plate 22). Near Solon, at the top of the stage, is a more massive 20-50-foot limestone, which is frequently dolomitised.

Small-scale current-bedding is often seen (39·800), and in a few places, ripple-marks. Near Kotla and Dadhag, the ripples have been

accentuated by subsequent compression.[1] Discontinuous structures, once formed, appear to have acted as avenues of relief to later stress. The strike of these ripples is 120°-300°.

Fracture cleavage is universal. The calcareous shales, thus cleaved, may be seen lying about the hill-sides as pencils and needles. Towards the east, the shale facies begins to show true oblique cleavage. Between Dadahu and the Tons river, the Krol A stage is recognised by the presence of banded grey and green slates (44·91), while northwards, near Milla and Mangal, the slates become puckered, veined with quartz, and almost phyllitic. The puckering at Milla is parallel to 130°-310°. In the east, distortion of the beds and lenticles of purer limestone becomes marked (Fig. 7 and Plate 22).

Black chert is common as thin bands, or in pillows up to nine inches long and three in height. At latitude 30° 33′ 22″: longitude 77° 44′ 51″, gypsum, with subordinate anhydrite, was found in a bed, 18 inches thick and 20 yards long, which appears to be an original deposit in the Lower Krol limestone.

In the Solon area, the apparent variation in thickness of these limestones is from 100 feet in parts of the south-west flank of the Belt, to some 2,300 feet, one mile south-east of 6,066 feet hill. The former thickness is due partly to reduction by thrust elimination, and the latter thickness to thrust multiplication. The real thickness probably varies from 300 feet on Pachmunda Hill to 700 feet on hill 6,066 feet. Within the area included by the maps, there seems to be no great variation, but further south-east, by Mussoorie and in Garhwal, these beds appear to become much thinner.

Krol B (red shales).

This sub-stage is characterised by soft, thinly laminated, purple-red shales, with blotches and intercalations of green shale. Thin dolomitic and cherty limestones are common. Ripple-marks are sometimes seen. Near the top of this division are parallel-bedded, shaly limestones similar to those in the Lower Krol limestone. The shales of this sub-stage are very incompetent; bedding is seldom preserved and their thickness is variable, owing to internal packing in the cores of folds and attenuation along the limbs. Slaty cleavage is never developed. Adjustment to stress takes place along countless

[1] Registered negatives (9× 12 cm.) Nos. 298, 299. Rock specimen No. 43·748.

irregular slip surfaces, in the greener shales, with formation of chloritic minerals. The maximum undisturbed thickness of these shales is about 300 feet.

Krol C.

This is the most conspicuous limestone on the hills round Solon, occurring in a single cliff from 150 to 300 feet in height. It is a massive, dark-blue, crystalline limestone, which usually stinks on fracture, and weathers to black 'chopping-board' surfaces. Dolomitisation is often seen.

Krol D (chert, limestone and shale sub-stage).

In this sub-stage are alternations of cherty limestones and shales, with shale usually in excess of limestone. The limestones are either pale or dark and stinking, in beds from ten to 30 feet thick. The chert is pale and occurs as thin wisps and in continuous bands up to two inches thick. The shales are of black, red, green and orange colours, the darker varieties often bleaching in a manner similar to those of the Infra Krols. Rare conglomerates occur, with pebbles of vein-quartz and of chert. Soft white sandstones are often found. Some of the limestones are penecontemporaneous breccias. The rocks of this sub-stage may be recognised on the terraced south face of Krol Hill, above the cliffs of the Krol C limestone, but their most characteristic development is between Bhaunrari and Mangarh, where the limestones readily twist into small scale overfolds in the great excess of shale (Plate 19). Gypsum was found as pockets replacing limestone near Bhaunrari. The minimum thickness of this sub-stage south-east of Narag is about 600 feet.

Krol E.

The rocks of this division afford rugged scenery, since they are seldom seen below 4,000 feet. Bedding is well developed, from one to five feet. The main rock type is a banded grey and pale cream-white microcrystalline limestone. Freshly fractured surfaces of the paler varieties are white and porcellanous. Thin crinkled veins of calcite are common in the form of 'sutures', which stand out slightly on a weathered surface. These limestones pass by increase of grain-quartz first to pale sandy limestones, in which the quartz grains stick out as small millet seeds, and finally to pale calcareous sand-

stones. More rare are saccharoidal crystalline limestones and cream-white limestones showing tubular and ellipsoidal growths of calcite, radial to cores of calcareous mud. These growths are deceptively like corals. Red, orange and black shales are present, but are subordinate in amount to the limestones. The minimum thickness of this sub-stage is about 500 feet. Between Mishwa and Dugana, the combined thickness of the C, D and E sub-stages is of the order of 3,000 feet.

Microscopical.

The Krol A limestones are very fine-grained and show clusters of carbonate in an almost isotropic matrix (22012) with quartz, sericite and pyrites (22013). In the more horny and siliceous varieties, carbonate is rare and sericite and quartz occur in a fine-grained to cryptocrystalline pulp (22014).

The limestones of Krol C and D are purer, showing simple mosaics. Stress results in idioblasts of coarsely crystalline calcite, from the size of a pin-head to nodules 2·5 cm. long, embedded in finer limestone (22018, 22019). Some of the cherty limestones show carbonate crystals embedded in cryptocrystalline silica.

The Krol E limestones are more interesting. Those that were sliced were chiefly sandy limestones. The sand grains are both angular and rounded, being found up to 2 mm. in diameter. Pellets of calcareous mud are common (22020). The grains of quartz have been corroded and replaced by carbonate which occurs as ingrowths obliterating former edges (22024). In 22027, microcline appears similarly to have been replaced. In the saccarhoidal limestones, quartz and calcite have crystallised out side by side, with the quartz showing good hexagonal sections (22025). Replacement of quartz by calcite should result in an increase in volume, since the molecular volumes of the two are respectively 22·67 and 36·85. No sign of strain due to expansion is seen, which is probably to be explained by the capacity for flow, rather than fracture, of limestone. Tourmaline is a common detrital mineral, particularly in the limestones round Mishwa (22027).

Tals.

These beds occur in two synclinal basins completely surrounded by Krols. When first encountered in 1930, the upper stage of the Tals was regarded as Jaunsar and the lower stage as Infra-Krol. Later they were considered to be a completely new series, lying normally above the Krols, and to be equivalent to the Tal beds described by Middlemiss in Garhwal.[1] This conclusion has been confirmed, with as much certainty as is possible in correlating between rocks of isolated basins.

[1] *Rec. Geol. Surv. Ind.*, XX, p. 36, (1887).

Medlicott[1] noticed beds belonging to the upper stage of these Tals on what was then called 'Korloe' peak. This peak is in approximately the position of Giltu ka Tibba, hill 7,005 feet (30° 40': 77° 29'). He was mistaken in correlating them with the Krols, and in underestimating their thickness.

The scenic changes from the rugged cream-white limestones of the Krol E stage, to the soft dark shales and graywackes of the Lower Tals, and from these to the pale cliff-forming Upper Tal quartzites, are very striking.

Sequence of Tal beds.

Upper Tals . .	Dark limestones and calcareous sandstones; quartzites; shales. Massive arkosic sandstones or quartzites; pebble beds; shales. Alternating quartzites, often pebbly, with shale or slate.
Lower Tals . .	Micaceous shales or slates with a few quartzites. Thick series of carbonaceous shales and dark graywackes, in massive beds marked out by finer banding and current-bedding. These pass laterally to tough slates and phyllites. Black chert beds and carbonaceous shales or slates.

The beds of the Lower Tals, particularly when converted into slates, are often very similar to those in the Infra-Krols. When uncleaved, they are usually to be distinguished by their more massive bedding, and by the abundance of dark graywacke, both features being absent from the Infra-Krols. The carbonaceous shales readily bleach, but generally as a uniformly weathering crust, and not in rings as in the case of the Infra-Krols. Many of the graywackes are strongly calcareous. Ripple-marks are sometimes seen. In the western basin, the Lower Tals vary from about 1,800 feet in the west to 3,500 feet in the east. In the eastern basin, they probably do not exceed 2,000 feet.

Quartzites form the most characteristic member of the Upper Tals (Plate 18). They are generally arkosic, and vary in colour from white to pale green. Occasionally there are found purple sandstones (7,216 feet peak). Current-bedding is universal and ripple-marks are common. Many of the sandstones are pebbly, containing pebbles of vein-quartz, green slate and pink feldspar, which is abundant and sometimes up to 10 mm. long. Pebbles of feldspar are not seen so often in the eastern of the two basins, though arkosic sandstones are common there.

[1] *Mem. Geol. Surv. Ind.*, III, p. 45, (1864).

Interbedded with the Upper Tal quartzites are purple, red, and green micaceous shales. Some of these are striking in their irregular vermicular tubes and nodules of pale sandstone. These shales were probably sub-aerially exposed, the turned-up edges of sun-cracked mud becoming filled in with later washings of sand. Near Gubsar, where the Tals have been tilted vertically in proximity to the Guma thrust, shales have been converted to puckered phyllites. Clay-slates are common in the northern part of the western basin.

The limestones are always dark, sandy and current-bedded. No fossils have been found. Soft sandy limestone may be seen to lie on hard, highly jointed quartzite (Plate 23).

The thickness of the Upper Tals, in the eastern basin, when not reduced by thrust faulting, is about 2,000 feet. In the western basin, it is probably, greater since the sandy limestones at the top are there preserved.

Allusion has been made to the similarity between the Lower Tals and the Infra-Krols, and between the Upper Tals and the Jaunsars. Differentiation between the Infra-Krols and Lower Tals is chiefly megascopic. The differences between the quartzites of the Jaunsars and the Upper Tals are as follows:—

	Jaunsar quartzites.	Upper Tal quartzites.
Tourmaline . . .	Rich	Not nearly so rich.
Plagioclase . . .	Rich	Poor.
Microcline . . .	Poor, except in Nagthat stage.	Rich.
Strain features . .	Strong, and marked by frittering along grain edges, ending with schistose structures.	Sometimes strong, and marked by new quartz mosaics. Quartz-schist never seen.
Megascopic appearance .	Generally dirty quartzites which may show intense ramification by veins of quartz. Frequently schistose.	Generally whiter, less horny and not so markedly permeated by quartz.

The shales and clay-slates of the Upper Tals lack the phyllitic and tough slaty condition usual to the Jaunsars. Phyllites in the Tals are rare. In manner of origin, it is probable that some of the Jaunsars and Upper Tals were formed under almost identical delto-continental conditions.

Microscopical.

Carbonate is present in all the massive graywackes. No ferromagnesian minerals, like augite or hornblende, have been found, such as are properly required

by the definition of these rocks, but the abundance of chlorite suggests formation from minerals derived from basic rocks. Biotite is common, but less so than white mica. The main part of the rocks consist of reconstructed quartz-chlorite-carbonate and quartz-sericite-carbonate. Chlorite occurs as laths, in hexagonal plates and in bundles (22034). Plagioclase may be common (22033). Some of the graywackes may be tuffs.

The grain-size of the Tal quartzites averages 0·50 mm. Most of the sections show abundant microcline (22039, 22041). Plagioclase is not common. Tourmaline is a frequent accessary (22038). Chlorite may occur as envelopes to the grains (22035). Clastic structures may be partly or almost wholly obliterated on account of recrystallisation, first as small-scale mosaics along the edges of grains, and finally, after passing through a stage of heavy strain shadows (22041), to a coarser interpenetration mosaic throughout the grain (22038). Bundles of sericite are formed.

In the arkose from the Gubsar locality, the clastic structure is still clearly discernible, particularly in ordinary light, but the strain shadows are severe and there has been incipient recrystallisation (22032). The associated puckered phyllite (22031) shows cleavage oblique to the bedding, and rotation of quartz grains in a gritty band. Abundant new mica has formed parallel to the cleavage, coalescing in directions perpendicular thereto.

Tertiaries.

It is not necessary to go into detail about the Tertiary rocks.

Subathus.

The Subathus consist of olive-green and purple, oily-looking shales, ramified with minute irregular joints, and by planes of movement which are often filled in by calcite. There are also green and white sandstones, iron-stained quartzites, and rare ripple-marked shaly sandstones. Shelly limestones and unfossiliferous sheared limestones, full of veins of calcite, are common. Well-preserved fossils are rare, the shelly limestones being made up mostly of broken oysters. Nummulites are seldom seen. Two characteristic facies, of limited distribution, are a ferruginous pisolitic laterite and carbonaceous bed, one specimen of which contains over 60 per cent. of carbon. Very occasionally, conglomerates made up of fragments of pale microcrystalline limestone, set in calcareous sandy mud, are found. The provenance of the limestone fragments is not known. They do not match any seen in the Krol series, nor those in the Subathu rocks themselves.

Near Kalka, along the Kawal Khal, and east of Dadahu, occurs an abnormal metamorphic facies of the Subathus. The purple and green shales become phyllitised and veined with quartz, while the carbonaceous shales are converted to dirty bleaching slates, exactly

similar to those in the Infra-Krols. Greenstones are locally common east of Dadahu. A band of massive limestone, thicker than is usually found in the Subathus, is strongly developed near Sataun.

Dagshais.

In the Kasauli neighbourhood, Col. Christophers has shown me a well-defined, white, quartzitic sandstone which intervenes between the Dagshais and the Subathus, and is a useful mapping horizon. The Dagshais proper consist of alternations of purple, cindery, sandy shales and purple or green sandstones, in beds up to 15 feet thick. The effect of these alternations on the scenery between Dagshai and Subathu is very striking. Current-bedding and ripple-marks are common. Conglomerates occur, containing the same type of limestone fragments as are found in the Subathu conglomerates, and also red shale derived from contemporaneous erosion. Between Dagshai and Subathu, these beds are 2,000 feet thick.

Kasaulis.

The Kasauli beds differ from the Dagshais in their general lack of purple colour, and in the predominance of sandstone over shale. The shales are less cindery, and greener. They may be either soft, or hardened to clay-slate. Some contain fragments of palm leaves. The sandstones are massive and generally hard.

Nahans.

The Nahans show the same regular alternation of sandstone and shale. The sandstones are massive, soft, green-brown in colour, rudely jointed, and coarsely current-bedded. The clays are chocolate and green in colour, and usually concretionary. Both sandstones and clays are streaked with purple.

Microscopical.

The Subathu sandstones are often calcareous, and owe their greenish colour to chlorite. Glauconite is fairly common (22042). The phyllitised Subathu shales show new chlorite associated with veinlets of quartz (22044).

The Dagshai sandstones are seldom calcareous. They contain fragments of phyllite, carbonaceous slate (Infra Krol or Subathu ?), rare limestone and Subathu-like sandstones. Minerals include tourmaline, garnet, plagioclase, kyanite, zircon and derived glauconite. They give the appearance of initial loose packing of phyllite and slate fragments with sand, and subsequent compression, with splaying-out of phyllite to yield new matrix (21951, 22046).

Garnet is common in the Kasauli sandstones (19225, 21941).

The Nahan beds (including Pilgrim's division of Sutlej beds, north-west of Subathu) are of interest in the frequent presence of fragments of volcanic rock (21946, 21945, 21948, 21947). These appear to be glassy andesites and basalts, the

latter largely chloritised. They differ from the greenstones found intrusive in the Subathus and Nahans east of Dadahu. Garnet, tourmaline, plagioclase, microcline, glauconite, and fragments of phyllite, carbonaceous, slate and limestone are common. Carbonate becomes an important constituent, in many of the Sutlej sandstones being over 10 per cent. of the rock.

Dolerites and Allied Rocks.

Basic hypabyssal rocks have been found in the following formations :—Jaunsars, Infra-Krol, the A, B, D divisions of the Krol limestones, the Subathus and the Nahans.

The dolerites in the pre-Tertiary rocks are occasionally found fresh and not sheared, but more usually are sheared and may even be converted to chlorite-schists. Most of the specimens are green with patches of white representing saussuritised feldspars.

The basic rocks in the Tertiaries are now greenstones. Shearing, and perhaps hydrothermal action, has been intense. No schists have been produced; instead there are innumerable irregular slip surfaces, so closely packed that it is impossible to obtain a good hand-specimen.

Microscopical.

Under the microscope the pre-Tertiary dolerites (22049-22057) are seen to contain :—magnetite or pyrites. apatite, augite, biotite, plagioclase feldspar, quartz. and alteration products.

Plagioclase is always in excess of pyroxene. Biotite is a common constituent. A graphic intergrowth of the later crystallised plagioclase with quartz is generally present.

The pyroxene is augite. Under stress it changes variously to antigorite, chrysotile, uralite and chlorite.

The biotite is usually associated with magnetite and chlorite.

The plagioclase is always zoned and varies in composition from oligoclase to andesine. It is generally badly saussuritised.

Quartz is common, both in individual crystals and in graphic intergrowth with plagioclase.

Carbonate is frequently found, resulting from the liberation of calcium on the break-down of augite and plagioclase.

These rocks range from quartz-oligoclase-dolerites to quartz-andesine-dolerites. They may be called comprehensively *leucophyres.*

The dolerites in the Tertiaries (22058, 22059, 22060) may belong to the same suite as those just described, though they show a greater quantity of feldspar and

quartz. The intergrowth of these two minerals is more involved, approaching micropegmatite. The augite is very seldom preserved, being represented by chlorite, uralite, magnetite, pyrites and calcite. The feldspar laths are generally completely saussuritised. Carbonate is abundant. The relative freedom of the quartz-plagioclase intergrowths from saussuritisation suggests that some of this may be of secondary origin, a hydrothermal effect more or less simultaneous with the movements which resulted in the break-down of the original dolerites. These rocks may also be called leucophyres.

V. DIFFICULTIES OF CLASSIFICATION.

A certain experience of the rocks of the Krol Belt has impressed upon one the fact of striking similarities between rocks of different series. The series as given in the table of formations, and as shown on the map, represent the outcome of weighing-out evidence of similarity and dissimilarity, and of studying sections in localities where the rocks have not been excessively disturbed. Once established, either in the text or on the map, the dissimilarities which led to the ultimate differentiation of the rocks tend, perhaps, to obscure the similarities which also exist. Given more or less complete sections, or given continuity along the strike, there is generally little difficulty in adjudicating the importance of similarity or dissimilarity, even when characteristic rock groups are missing, since the position of the rocks with reference to other known stages, about which there is no question as to which series they belong, by itself yields information. In many places, however, thrusting and folding have been so severe that single stages occur in abnormal positions, and die out without anywhere showing, in their small outcrops, characteristic rock facies of diagnostic value. In such circumstances, neither lithology nor position can assist in determining to which group they belong, and their assignation may be extremely difficult. As examples may be mentioned :—

(1) The outcrops along the Giri river from Tikari to the confluence with the Jagar ka Khala, which are mapped as Infra-Krol.

(2) The outcrops, 14 miles in length, from Chiyan to beyond Sataun, mapped as Infra-Krol.

(3) The outcrops round Rajana, mapped as Lower Tal.

(4) The outcrops between heights 2,820 and 2,795 feet on the Giri river, where an arbitrary line has been drawn between the Simla slates and the Jaunsars.

Characteristic facies of diagnostic value.

Simla slates.—Chhaosa slates; Domehr slates; striking at Domehr, but untypical at Kandaghat.

Jaunsars.—Purple conglomerates with 'eggs' of vein-quartz; very inconstant. Crinkled slate-blue phyllite, strongly interbanded with thin phyllitic quartzite. Massive, blue, crystalline, sandy limestone (Bansa limestone).

Blaini.—In its normal position between Simla slates or Jaunsars, and Infra-Krol, is very striking; but see Mandhali question, page 419.

Infra-Krol.—No single unique characteristic.

Krol limestone.—*Krol D*:—some cherty limestones; of diagnostic value only in differentiating between the various Krol limestones;

Krol E:—cream-white porcellanous limestones;

The sub-stages do not often occur singly and completely isolated in foreign rocks. Combination of characters and relative position is of great value.

Tals.—Nature of bedding in Lower Tals and microscopic characters (microcline) in Upper Tals.

Subathus.—Olive-green and purple, oily-looking shales, with cuboidal jointing.

Lithological characters common to more than one series.

(1) Black, apparently carbonaceous, shales or slates, which readily bleach, and often contain pyrites:—

Simla slates, Mandhalis, Jaunsars, Blaini, Infra-Krol, Krol sandstone, Krol D, Subathus.

(2) Banded, black and grey, 'varved' slates and gritty clay-slate:—
Jaunsars, Blaini, Infra-Krol.

(3) Purple phyllites:—

Mandhalis, Nagthat stage, Subathu rocks locally sub-phyllitic.

(4) Red shales:—

Jaunsars, Blaini, Krol B (Tertiary red shales are more distinct).

(5) Conglomerates and pebble beds:—
Simla slates, Mandhalis, Jaunsars, Blaini, Krol D, Tals, Subathus.

(6) Boulder beds:—

Mandhalis, Jaunsars, Blaini.

(7) Arkoses:—

Jaunsars, Tals.

(8) White sandstones or quartzites:—

Simla slates, Mandhalis, Jaunsars, Blaini, Infra Krol, Krol sandstone, Krol D, Krol E, Subathus.

(9) (*a*) Lenticular limestones in calcareous shale or slate:—

(*b*) Thin-bedded, blue, microcrystalline limestones:—

Mandhalis, Krol A.

(10) Sandy limestones:—
Mandhalis, Jaunsars, Krol E, Tals.

(11) Shelly limestones:—

Tals, Subathus.

Sedimentation characters common to more than one series.

(1) Ripple-marks :—

Simla slates, Jaunsars, Krol A, B, D, Tals, Subathus, Dagshais.

(2) Current-bedding :—

In the sandstones and quartzites of all the series.

(3) Mud-cracks :—

Jaunsars, Tals.

It is evident that most of the series were deposited under shallow water, epicontinental, conditions. The Jaunsars and the Upper Tals were probably continental formations, deposited in piedmont and fluvial environments.

VI. REPETITION, CURRENT-BEDDING AND INVERSION.

It has been seen that the resemblance between facies members in what have ultimately been regarded as different rock series is often striking. In the field it has led to uncertainty in mapping, since similarity might be due to two causes :—

(1) Repetition in the course of time of similar sedimentary conditions ; the existence, therefore, of distinct sedimentary series.

(2) Repetition of a single series by tectonic movements—

(*a*) by thrusting ;

(*b*) by overfolding, with inversion.

When the beds which are now regarded as Upper and Lower Tals were first encountered in the Nigali syncline, I took them to be respectively Jaunsars and Infra-Krols. On this interpretation, supposed Jaunsars overlay supposed Infra-Krols and these, in turn, rested on Krol limestones. Close by, known Jaunsars had been found normally to underlie known Infra-Krols (with the Blaini intervening). The thought, in fact the hope, presented itself that a great overfold had been found, causing the repetition, in inverted order, of Jaunsars and Infra-Krols above the Krol limestones.

Correct succession.	*Possible succession.*
Upper Tals	Inverted Jaunsars.
Lower Tals	Inverted Infra-Krols.
Krol limestones	Krol limestones.
Infra-Krols	Infra-Krols.
Blaini	Blaini.
Jaunsars	Jaunsars.

Current-bedding.

To decide if this were so, the current-bedding surfaces of the quartzites which are now regarded as Upper Tals, and of those in the true Jaunsars, were examined. The principle involved is that in undisturbed areas, the current-bedding surfaces face concavely upwards. If cases are found in which the current-bedding surfaces face convexly upwards, it may be assumed that the beds in question are inverted.

Cloos[1] appears to have been the first to use this method, while it has been employed with considerable success by Prof. Bailey and others in Scotland.[2]

Cases are found in which the current-bedding occurs as plane-surfaces, oblique at a constant angle to the true bedding. Other cases are seen in which the curves of current-bedding are inflected, and asymptotic both towards the top and bottom of the bed of sandstone. These are rare, and are of no use in demonstrating inversion. Inflected forms have occasionally been seen in the Siwalik sandstones, and in the sandy Bansa limestone of the Jaunsars, but they are very uncommon in comparison with the normal type of current-bedding surfaces which are truncated above, and asymptotic below.

Prof. Boswell has been kind enough to write to me on this subject. He states that in experiments which he and Prof. Wilton have carried out on the deposition of sand of average diameter 1-100th of an inch (0·25 mm.) in glass-sided troughs, the following results were obtained :—

(1) With moderate velocity, up to 1·2 feet per second, ripples of wave-length of about three inches were produced, and current-bedding occurred of inflected form, asymptotic at the top and base.

(2) With increased velocity, up to 1·5 feet per second, the tops of the ripples were eroded to a plane-surface, abruptly truncating the bedding.

(3) With still higher velocities, larger 'whale-back' ripples were formed, of wave-length of ten or more inches, on the lee side of which the bedding, although asymptotic at the top of the mounds, abutted abruptly on to the floor of the underlying material.

The commonest type found in sedimentary rocks corresponds to that in section (2); that of section (1) has been seen, but is not

[1] *Zeitschr. f. prakt. Geol.*, p. 340, (1914).
[2] *Geol. Mag.*, p. 68-92, (1930).

common; that of section (3) I have not seen. In the Kaimur rocks of the Vindhyan plateau, current-bedding is universal, and is always of type (2). Contradictory cases, in which the current-bedding is convex upwards, do occur in sedimentary rocks, and are ascribed by Prof. Boswell to exceptionally high velocities of transport.

It is agreed that, given a large enough number of cases, and neglecting those that are ambiguous, it is possible to use the disposition of current-bedding as a means of determining whether inversion has taken place.

When applied to the Tal quartzites of the Nigali syncline (Plate 23) and to the Jaunsars of the cliffs overlooking the Tons river, it was found that both sets of quartzites were in a normal, uninverted condition. It was impossible, therefore, to suppose that the Upper and Lower Tals were inverted Jaunsars and Infra-Krols in the middle limb of a recumbent fold. The alternative explanations were either that thrusts had brought uninverted Jaunsars and Infra-Krols on to Krols, or that the rocks in question belonged to a later series than the Krols, in normal order above them. A wider experience of the rocks above the Krols showed that the two divisions graded into each other, by the increase upwards in number of quartzitic bands. The change in lithology is so gradual that it was impossible to map the boundary between the two divisions within a range smaller than 200 feet.

Further, no sign of Blaini beds has ever been seen between the two divisions. The Blaini is, it is true, sometimes eliminated from the normal Jaunsar-Blaini-Infra-Krol succession, but never extensively so. If thrusts had brought Infra-Krols over Krol limestones, and Jaunsars over both series, it would be very surprising that the Blaini, which normally intervenes, should never be seen incorporated in the thrust masses.

These facts, together with the lithological differences enumerated on page 391, seem sufficient to warrant the belief that the beds overlying the Krol limestones belong to a later series. The occurrence in Garhwal of Tal quartzites overlying massive limestones, similar to the Upper Krol limestones, is enough to clinch the matter, because in Garhwal there is not the same difficulty of the existence of an underlying, highly quartzitic series with which the Tal series could be confused.

The disposition of current-bedding has further shown that the Simla slates in the Gambhar river to the south-west of Simla, the

Jaunsars north of the Giri river (east of Dadahu), and the Jaunsars north of Kando, are in a normal, uninverted order.

Inversions in which strata have been folded through 120°, are fairly common, especially along the north face of Kamli Dhar. These have come to light as a result of mapping, since the stages concerned do not contain current-bedded sandstones. Further, minor flat folds are often seen from a distance in the limestone bands of the Krol D stage, but these occur on a small scale in rocks, which, taken as a unit, are in normal order (Plate 19).

As applied to the Krol Belt, the examination of current-bedding has been of most use in deciding whether or not the great outcrops of quartzites of the Tal, Jaunsar and Simla series have been completely inverted in large-scale recumbent folds.

The general structure of the Krol Belt is clearly one of uninverted, or only slightly overturned, sequences, which have been brought forward by thrusts, and not of recumbent folds.

VII. ORIGINAL SPATIAL RELATIONSHIPS BETWEEN DIFFERENT SERIES.

Simla Slates, Jaunsars, Blaini (? Mandhali).

The sequence given by Pilgrim and West was in descending order :—Blaini : Simla slates : Jaunsars.

This was based on two main considerations :—

(1) The Blaini was found most usually to overlie Simla slates.

(2) The Jaunsars appeared to be more metamorphosed than the Simla slates and were therefore regarded as older than them.[1]

Between the Gambhar and Giri rivers, Jaunsars had been found to overlie Simla slates, usually with supposed Blaini intervening. The explanation given was that Jaunsars had been thrust into an abnormal position upon the Simla slates with their capping of Blaini. Any Infra-Krol slates and Krol limestones that might originally have overlain this Blaini, were thought to have been planed off from the Blaini and pushed south over the present belt of Krol rocks.

Subsequently it has been found that over wide stretches of the Krol Belt, particularly in the east, Infra-Krol and Blaini lay directly

[1] Pilgrim and West, *op. cit.*, p. 21.

upon Jaunsars. There was also evidence that the Jaunsars which overlay the Simla slates of 6,474 feet hill and Kandaghat, without the intervening boulder bed and limestone, might in reality be in a normal stratigraphical order upon them.[1] It was therefore suggested that the correct sequence might be Blaini : Jaunsars : Simla slates.

The greater general degree of metamorphism shown by the Jaunsars may be regarded as an accident of their lithological composition and of their position with reference to zones of greater stress.

This question is more complicated than was supposed in 1928. I had tended to ignore the usual occurrence of rocks resembling the Blaini between the Jaunsars and the Simla slates.

In places where I had worked in 1928, the intervening supposed Blaini was absent. There was an apparent lithological gradation from Simla slates upwards into Jaunsars, as may be seen on the Kandaghat-Chail motor road near Senj, and along the Subathu-Kathlighat mule-track between distances of four and 4½ miles from Kathlighat. Purple slates and quartzites increase in importance in the Simla slates, until they are finally succeeded by more massive Jaunsar quartzites with associated green and purple beds.

At the opposite, eastern, end of the Krol Belt, the Mandhali rocks, with boulder beds, pink limestones, and a complex association of conglomerates, quartzites, purple phyllites, bleaching slates and limestones, have recently been found to underlie Jaunsars and to occur above a series of sandstones, quartzites, shales and slates which are equivalent to the Simla slates.

The nature of these Mandhalis is obscure. Oldham, Pilgrim and West all tentatively correlated them with the Blaini and Infra-Krol. If this be so, the Jaunsars must lie as a thrust mass upon Mandhalis, in a manner comparable to their thrust position inferred by Pilgrim and West on the Blaini in the Simla area.

The question of the Mandhalis will be discussed in a later section (page 419). Here I shall just state the view that the Mandhalis may be possibly a series which occurs normally at the base of the Jaunsars. There may, in fact, be two distinct groups of boulder beds and limestones, hitherto both called Blaini, one at the base of the Jaunsars, between them and the Simla slates, called the Mandhalis, the other at the top of the Jaunsars, below the Infra-Krol, the Blaini *sensu stricto*.

[1] *Rec. Geol. Surv. Ind.*, LXII, p. 166, (1929).

On this view, the whole outcrop of the so-called Blaini between Simla and south of Badgala which occurs between Simla slates and Jaunsars may be Mandhali. The Jaunsars in this case would be in normal position upon the Mandhalis, without an intervening thrust.

At Badgala Pilgrim and West (page 26) describe the occurrence of slates and a massive limestone which they suggest may be Infra-Krol and Krol. It is possible that these slates and limestone are really equivalent to those found in the Mandhalis of Kalsi.

These authors also (pages 87, 88) describe a sequence of Blaini: Jaunsars: Simla slates at Piran and Pajal which was puzzling on the belief that the Jaunsars normally occurred below the Simla slates. Their suggested explanation (pages 118, 119) is that the Blaini lay upon an eroded overfold in which Jaunsars had been brought abnormally and inverted above Simla slates. If, as is here suggested, the correct sequence is

Blaini,
Jaunsars,
Mandhalis,
Simla slates,

there would be no need to assume the existence of an overfold. But the difficulty is not cleared, since on the south-west and north-east sides of the Mangred Khala, the sequences as mapped are

South-west side.		*North-east side.*
Chails		
........*thrust*		
Jaunsars.		
Blaini..............	*continuous outcrop*	............Blaini
		Jaunsars
Simla slates..........	*continuous outcrop*	............Simla slates

The explanation that I would offer is that the Blaini on both sides of the Mangred Khala is really Mandhali, and that the Jaunsars that are mapped between it and the Simla slates on the north-east side of the river, are a local conglomeratic facies of the Mandhali, such as is often found in the Kalsi area, and by mile 33 on the Chakrata-Mussoorie mule-track.

The relationship between Simla slates and Jaunsars along the Giri river from below Shaluman to Dadahu is little understood Between Mareog and Barog (not the Barog of the Kalka-Simla Railway), typical Chhaosa slates are developed. To the south.

east, the Chhaosa slates are no longer recognisable. Instead, there is seen a series of thin-bedded, tough, dark slates, often well cleaved, and sometimes ramified by veins, lenses and sills of quartz. One mile south-east of Narail, they have a typical Jaunsar aspect, with purple and white, massive, ripple-marked quartzites, (Plate 21, fig. 2). By Siyun, the same slates are barren of quartzites, but contain sheared dolerites. In the Palor ka Khala, these Siyun slates pass upwards to undoubted Jaunsars, with conglomerates and purple phyllites. The slates at Siyun were mapped by Pilgrim and West as Simla slates, but they accord better with a Jaunsar designation.

No boundary between the Jaunsar and Simla series was discernible, though it must occur near the boulder beds and limestones which come down to the Giri river from Badgala. The slates have been mapped in sheets 53 F/5 and 6 as Jaunsars, and in 53 F/1 as Simla slates. The boundary drawn at the junction of sheets 53 F/1 and 5 is purely arbitrary.

East of Dadahu the Jaunsars assume a great thickness and appear to consist of three stages, described on pages 368 to 374. Of these stages, that of Nagthat is most typical of the Jaunsars of the Simla area, but there is a horizon of conglomerates and grits in the Mandhalis that also resembles the Simla Jaunsars. The rocks at Chakrata are Simla slates, and are separated from the Jaunsars by the Tons thrust. The apparent sequence in the Chakrata area is

Nagthat stage	Jaunsars.
Chandpur stage	
Mandhali stage	
	Tons thrust.
Simla slates with occasional Nummulitics.	

Blaini on Jaunsars and Simla Slates.

The nature of the relation of the Blaini to the rocks which underlie it is complex. The following is a list of the main types of occurrence of Blaini which occur *in normal succession below Infra-Krol and Krol* :—

(1) *Blaini on slates similar to Infra-Krol slates* :

(*a*) Middle reaches of the Blaini river.

(*b*) Spurs north-east and south-east of hill 4,960 feet.

(*c*) Kawal Khal, below height 3,241 feet.
(*d*) Spurs between Jamthali and the Giri river.

These slates should properly be mapped as Blaini but it would be impossible to separate them from the Infra-Krol in places where the Blaini boulder beds or limestones are missing.

(2) *Blaini on Simla slates :*

(*a*) One mile east of Solon.
(*b*) In the Kawal Kahl at Masria and Marcog.

(3) *Blaini on Jaunsars :*

(*a*) Along the lower reaches of the Blaini river.
(*b*) Between Rerli and Shiwa Kalan, a distance of 22 miles.

By regarding the slates of Infra-Krol type, which are associated with the Blaini, as belonging to the Blaini, no problem is involved as to their relation with the boulder beds and limestones. They may be considered simply as local intercalations of varved sediments below and between tillites.

The problem becomes one of understanding the nature of the occurrence of Blaini both on Simla slates and on Jaunsars.

Bedding discordance has nowhere been seen between the Blaini and the underlying rocks. The unconformity that exists, even though regionally considerable, is not of orogenic violence.

The Blaini boulder beds are made up almost entirely of slates and quartzites derived from the Simla slates and Jaunsars, and clearly indicate extensive erosion of these formations.

Unconformity.

Proof of unconformity has come to light as a result of mapping the great syncline of Tals, Krol limestones, Infra-Krols and Blaini which runs from Giltu ka Tibba (hill 7,005 feet), to Handera Tibba (hill 6,458 feet). The Blaini on the northern limb of this syncline lies on a great thickness of Jaunsars, of the order of 10,000 feet. The Blaini on the southern limb of the syncline rests on at most 2,000 feet (in both cases neglecting the Mandhalis). Some of this discrepant thickness is due to thrusts, since, in the eastern part of the southern limb of the syncline, Tals rest direct on Jaunsars, with Krols, Infra-Krols and Blaini all cut out. In the west, however, the whole Tal-Blaini succession is present, only slightly complicated by minor thrusts, and the

Blaini still rests on a diminished thickness of the Jaunsars. It is the Chandpur stage that is almost completely eliminated.

Since the region from which the Chandpur stage was eroded appears to coincide with the southern limb of the present Tal-Blaini syncline, it follows that the original axis of uplift responsible for the erosion, must have been or less parallel to this limb. This implies that the axis had a Himalayan trend, in contrast to an Aravalli trend.[1] Had there been an Aravalli N. E.-S. W. axis, it would have been impossible for the Jaunsars to be both attenuated by erosion, and fully preserved from erosion, along this single alignment.

In places where the Blaini rests directly on Simla slates, it may be assumed that the Jaunsars had been completely eroded away previous to the deposition of the Blaini. Such erosion must have been local, because, while Blaini rests on Simla slates along parts of the Kawal Khal, and near Solon, it is found on Jaunsars again further to the north-west, along the lower reaches of the Blaini valley. Further, across the Ashmi-Giri rivers to the north-east of Solon and the Kawal Khal, Jaunsars are found in a continuous and wide outcrop which runs without a break from the Gambhar river to south of Badgala.

Accepting that the Mandhalis occur normally between the Jaunsars and the Simla slates, it follows that an unconformity which brings Blaini, Infra-Krols and Krol limestones across the Jaunsars on to the Simla slates, must bring Blaini locally in contact with the Mandhalis. Such contact of Blaini with Mandhalis would lead to great difficulty of mapping, owing to the similarity between the two divisions. It is believed that this *a priori* case may be illustrated by outcrops between longitudes 77° 40′ and 77° 49′, along latitude 30° 33′.

The position may be summarised as follows, accepting here the viewpoint taken up later in the discussion on the Mandhalis.

(1) There is at least a possibility that there are two distinct series of boulder beds and limestones, called Mandhalis and Blaini, in the following sequence :—

Infra-Krols,
Blaini,
Jaunsars,
Mandhalis,
Simla slates.

[1] *See page 449.*

(2) The true Blaini, with overlying Infra-Krol slates and Krol limestones, rests with unconformity upon both the Jaunsars and the Simla slates. This unconformity is great, but in no section has bedding discordance been seen. The folds that led to erosion of the Jaunsars must have been gentle. It is probable that these folds had a Himalayan trend.

Blaini and Infra-Krol.

As previously stated, slates of Infra-Krol type are often intimately associated with the Blaini limestones and boulder beds.

In the simplest case, Blaini limestone appears to pass up gradually, by increase of shale matter, into pink, greenish, and finally black shales of the Infra-Krols.

The abundant bands of brown-weathering, calcareous, gritty clay-slate which occur in the Infra-Krol may be considered to be small-scale repetitions of the Blaini limestone throughout the lower part of the Infra-Krol succession.

Infra-Krol, Krol Sandstone and Krol Limestones.

The typical relations of the Infra-Krol to the succeeding stages are seen round Solon. Here the dark or black shales of the Infra-Krols pass up through a transition zone of 100 feet or so to Krol sandstone, and this in turn to more dark shales, before the green calcareous shales and thin-bedded limestones of the Krol A stage set in. Viewed from a distance, as towards the north-west ridges of Rajgarh Hill from Khanog Hill, the change from the black Infra-Krol shales to pale Krol sandstone appears abrupt. When examined at close quarters, the change is found to be gradual.

The Krol sandstone has not been seen east of the western slopes of hill 3,619 feet, nor along the greater part of the north-east flank of the Krol Belt between the Kawal Khal and the Jagar ka Khala. It is only two feet thick in the Giri river half a mile north of Dadahu.

When the sandstone is absent, passage from Infra-Krols to Krol A limestones is shown by a gradual increase in the number of shaly limestone bands. Plate 21, fig. 1, shows the base of the Krol A limestones, where black shales alternate with shaly limestones and calcareous shales.

On account of the varied thickness of the Krol sandstone, Oldham [1] and Pilgrim and West[2] believed that the Krol limestones were unconformable to the Krol sandstone.

This view in my opinion has little justification. Part of Oldham's argument in any case fails, because his objection that the adjacent quartzites in his Carbonaceous series are of far greater thickness than the Krol sandstone with which they were correlated, therefore indicating that considerable erosion of the Krol sandstone had taken place, no longer stands now that those quartzites have been found to belong to a much older Jutogh series.

The intimate interbanding of shale and sandstone and the gradation from Infra-Krol, through Krol sandstone, to Krol A, do not warrant the belief that any break of sedimentary conditions occurred. A truer picture is obtained by regarding the Krol sandstone as a local sandy intercalation amongst the shales and shaly limestones.

If there be unconformity at all, it should be between the Krol sandstone and the Infra-Krols, since discs of Infra-Krol shale are often found in the sandstone, and in one case a wash-out was observed at the top of the Infra-Krols. These phenomena in my opinion prove little except that currents churned up some of the recently deposited black muds.

Medlicott saw no reason for supposing the existence of an unconformity. With that view I am in agreement.

Krol D.

The existence in the Krol D stage of conglomerates and pebbly sandstones, together with limestone breccias, suggests a slight break in conditions of sedimentation. The break cannot have been important, because nowhere is there any evidence of erosion of the underlying stages of the Krols. The exact relations of these conglomerates to their contemporaneously deposited limestones is obscure. Folding near Mangarh has obliterated all the original sedimentary relationships.

Krol Limestones and Tals.

Over the greater part of the synclinal basins in which the Tals occur, Lower Tals rest on Upper Krol limestones.

[1] *Rec. Geol. Surv. Ind.*, XXI, p. 138, (1888).
[2] Pilgrim and West, *op. cit.*, p. 134.

South of Guma peak, Upper Krol limestones have been thrust directly on to Upper Tals. This is a tectonic relation.

From south of Khur to Chiyanra, the lower Tals rest on Infra-Krols. This is due probably to a combination of original unconformable overlap of Tals across the stages of the Krol limestones, and of later tectonic elimination. Middlemiss has shown that a slight unconformity exists between the Tal beds and the underlying Massive (Krol) Limestone of Garhwal.

No Tals have been seen on the Krol E limestones south-east of the Giri river, though Subathus occur there. Tals were probably never deposited south-west of the Giri river, since, in those places where they are now found on Krols, they appear to have exerted a protective influence on the underlying limestones and shales, preventing them from folding intricately amongst themselves. It is probable that the strongly folded Krol limestones south-east of the Giri formed more elevated land during the period of Tal deposition, but were submerged below the sea at the end of the Mesozoic.

Tals and Subathus.

No case has been seen of Subathus resting on Tal beds. This is in contrast to the Garhwal area, where Middlemiss found the two series to be commonly associated.

Krol Limestones and Subathus.

Between Janot and Sainbar Hill, there is found a collection of black, brown, olive-green and purple, splintery shales, dirty pebbly quartzites and sandstones, and lenticular, blue, shelly limestones which are wedged in the Krol D and E limestones.

At the hill one mile west and south-west of Bongli (hill 6,048 feet on the two-inch map-sheet 313 N. E.), the interbedding of lenticular shelly limestones and brown and green shales with the Krol E rocks is so parallel that the rocks were taken to be authentic fossiliferous Krols. The occurrence of characteristic purple and olive-green cuboidal shales with similar limestones and brown shales at Bagar is strong indication, however, that the whole lot were Subathu.

The fossils are rare and very badly preserved. They are all broken, and, like those in the Subathus, they give the impression of having been mostly oysters that had been current- or wave-tossed on shelly marine banks.

Mr. Wadia has kindly made an examination of these fossiliferous limestones. He writes :—

'Foraminifera are absent, except in one doubtful specimen. Besides many broken bivalve shells (probably *Ostrea*), there is found a turritellid gasteropod, and some black enamelled scales like placoid fish scales. There also occur numerous fish bones, spines and dental plates in a highly fragmentary state in the limestone.

From their general lithological aspect, these limestones may be thought to belong, with equal possibility, to the Triassic or to the grey-black, partly bituminous, shelly, Subathu limestone. On the whole I think the latter supposition is the more probable.'

The decision must rest upon the extremely Subathu-like aspect of the olive-green and purple cuboidal shales, and accordingly these rocks have been mapped as Subathu.

It should be pointed out that the limestones just described, which are regarded as Subathu, as well as true Subathu limestones and the Tal limestones of Garhwal, all contain broken fossils, most of which appear to be oysters. It is most unlikely, however, that the limestones found between Janot and Sainbar Hill are Tal. The Tal limestones are almost invariably sandy, and occur associated with sandstones or quartzites rather than with shales. The Subathu limestones are seldom sandy (though under the microscope, they may be seen to contain a few grains of quartz), and they are always associated with shales.

The Floor to the Nummulitic Sea.

In Garhwal, Nummulitics rest on Mesozoic Tal beds. In Sirmur State, they are seen on Krol limestones. At Subathu and at Dabra, they occur on Simla slates.

It is clear that a considerable part of the Himalayan area must have been beneath the sea during the early Tertiary, and that there must have been extensive previous erosion to allow for the occurrence of Nummulitics on rock series of such different ages.

The unconformity of Tals on Krols, and the probable formation of the Tals from denudation of closely adjacent montane areas, suggests that erosion in this area did not take place at a single time, immediately preceding the Tertiary period, but was persistent throughout the Mesozoic.

Medlicott's views are expressed on pages 86 and 87 of his memoir. At the time of his survey, Nummulitic rocks had not been found

on Krols, or amongst his crystalline and sub-crystalline rocks to the north-east. Accordingly he was led to believe that

> 'the pre-nummulitic elevation was effected on the same lines, so to speak, as those which now mark the Himalayan mountain system',

thereby forming a land barrier to the north-east which prevented deposition of the Nummulitics in that direction. As a consequence of the bedding conformity seen between the Subathus and the underlying Simla slates at Subathu, Medlicott claimed that

> 'The fact of such extensive denudation having affected the older rocks prior to the nummulitic period, implies that these rocks had also undergone disturbance, and it is of importance to be able to indicate the nature of that disturbance; *it was in no sensible degree the disturbance which produces contortion or flexure of strata.*'

Support for this contention was thought to exist in the fact that the Nummulitics show as much disturbance as do the older rocks upon which they rest, from which it was concluded that the older rocks were more or less undisturbed at the time of the deposition of the Nummulitics.

Since the publication of Medlicott's memoir, Nummulitics have been found 'inland' of the main belt of Tertiary rocks. In the Simla area, they have been mapped as far north as Shali peak. They have also been found on the Krol and Tal rocks of the present Krol Belt between Solon and Naini Tal, and occur at Dabra, north of the Tons thrust. The postulated pre-Nummulitic elevation was, therefore, less well-defined as a barrier than Medlicott supposed.

Medlicott's argument concerning the parallelism of dip between the Subathus and the Simla slates clearly does not express the full facts of the case. On page 83, he admits that the entire evidence relating to the geological history of the Nummulitic rocks depends on the section at Subathu. This section cannot be said to be striking, even allowing for the fact that 80 years ago it may have been less obscured by bazar filth, and it is probably a pure accident that just there the Subathus and Simla slates show bedding conformity.

Evidence has been given elsewhere [1] for supposing that in Palæozoic times, the pre-Triassic rocks of the present Himalaya, in the Simla-Chakrata-Naini Tal area, were subject to orogenic activity along north-east to south-west, or Aravalli directions. Middlemiss also noticed that in the Kumaon Himalaya, there was

[1] Auden, *Rec. Geol. Surv. Ind.*, LXVI, p. 461, (1932).

to be found disturbance along north-south lines oblique to the strike usually found in the Tertiary and some of the pre-Tertiary rocks.[1]

The greater general degree of metamorphism, cleavage and crushing shown by the Palæozoic and Mesozoic rocks in the Himalaya cannot be attributed to the mere factor of time, since time alone will leave Algonkian sediments as unaltered as recent ones. Stress must have played a part, and one that is hardly consistent with the total absence of folding or flexure which Medlicott supposed. It is further probable that the Hazara, Chor, Lansdowne and Dudatoli granites may have been intruded towards the end of the Palæozoic.

Medlicott's other point, that the pre-Tertiary and the Tertiary rocks show the same degree of folding, is an indication, not that the earlier rocks had not been previously folded, but that the later Himalayan movements were as intense as any that had preceded, and had caused structures of equal complexity.

It is clear, therefore, that the pre-Tertiary rocks had undergone a more varied history than the simple erosion from approximate horizontality into plateaux and valleys, which had been postulated by Medlicott. Had he omitted the word *flexure*, his position would have been sounder, at any rate for the times occupied by deposition of the Infra Krol, Krol limestones and Tals.

VIII. METAMORPHISM.

General.

From the foregoing lithological descriptions, it is seen that the rocks of the Krol Belt show the following grades of alteration:—

Shales, slates, clay-slates, phyllites, schistose phyllites; sandstones, quartzites, quartz-schists; limestones, recrystallised limestones; dolerites, greenstones.

The whole series is typically one formed under *epi*-conditions. Mica-schists, with index minerals of higher grade, quartzites that have been recrystallised to a new mosaic with complete loss of clastic structures, limestones with calc-silicate minerals, and hornblende-schists, have nowhere been found.

[1] *Mem. Geol. Surv. Ind.*, XXIV, pp. 125-129, (1890).

The argillaceous rocks have not been metamorphosed sufficiently for the microscope to be of much value in determination. Most of the slates and phyllites, which in hand-specimen are characteristic, are not particularly distinctive in thin sections. The differences amongst these argillaceous rocks are on the whole megascopic, rather than microscopic.

Amongst the argillaceous rocks, newly-formed quartz, sericite and chlorite are fairly universal. Blasto-biotite has not been seen.

Some of the quartz-schists of the Jaunsars are sufficiently metamorphosed for the clastic structure to be almost obliterated. Mosaics of recrystallised quartz are frequently found, but never completely throughout the body of the rock.

In the limestones may be seen idioblasts of calcite. Many of the Upper Krol limestones have been completely recrystallised, and infested with sigmoid veins of calcite (43·758), but, even when siliceoüs impurities are present, there has been no sign of the formation of calc-silicate minerals. A striking feature of most of the limestones is the recrystallisation side by side of quartz and carbonate, and the frequent replacement of quartz by carbonate. It is clear that stress has acted on these rocks without the influence of any considerable temperature, since wollastonite is not formed.

The dolerites are readily susceptible to change, but, in spite of uralitisation and saussuritisation, they can always be recognised as basic hypabyssal intrusives.

Distribution of Metamorphic Effects throughout Succession.

Tabular statement of Metamorphic Effects.

	Schistose phyllite ; knotted slate.	Phyllite.	True slates with oblique cleavage.	Clay-slates.	Crushing parallel to N.E.–S.W. directions.	Injection with quartz-veins due to crushing.	Flowed limestone.	Jointing.
Nahans								Coarse and irregular
Kasaulis . . .				*				Fairly good.
Dagshais . . .								Irregular.
Subathus . . .		sub-phyllitic.		*		*		Very irregular.

Tabular statement of Metamorphic Effects—contd.

	Schistose phyllite; knotted slate.	Phyllite.	True slates with oblique cleavage.	Clay-slates.	Crushing parallel to N. E.–S. W. direction.	Injection with quartz-veins due to crushing.	Flowed limestone.	Jointing.
Upper Tals . . .		•		•		•		Strong clean-cut.
Lower Tals . . .			•			•		Strong clean-cut.
Upper Krol Limestone .								Irregular.
Red shales . . .								
Lower Krol limestone .		sub-phyllitic.	•	•		•	•	
Krol sandstone . .						•		
Infra-Krols . . .	•	•	•	•		•		
Blaini	•	•	•	•	•	•		
Jaunsars . . .	•	•	•	•	•	•	•	Strong clean-cut.
Mandhalis . . .	•	•	•	•		•	•	
Simla slates . . .		•		•		•	•	

The above table shows that it is impossible to differentiate the rocks of the Krol Belt by their metamorphic condition.

No rigid list of characters can be assigned to any particular series of rocks present in the Krol Belt. There is no regular decrease in metamorphism, varying directly and discontinuously, with the division of the rocks into discontinuous series.

What is not seen in the table is the fact that most of the series show rocks of varied degrees of metamorphism.

In the Simla slates and Kasaulis, soft green needle-shales occur interbedded with clay-slate.

In the Jaunsars occur sandstones, quartzites and quartz-schists in close association. Single beds of quartzite may be marked out by extreme permeation with vein-quartz, due to crushing, while adjacent beds are free from veining. Clay-slates, slates, phyllites and chlorite-schists all occur close together, the green beds being particularly susceptible to alteration.

In the Blaini, red shales occur with banded slates. In the Krol, marmorised Krol C limestone may be seen to lie on unaltered red shales which have been penetrated by sheared greenstones (dolerites).

In the Subathus may be found gradation from soft purple and green shales to hard, tough, phyllitic clay-slates, penetrated with veins of quartz. Middlemiss noticed the same feature in the case of the Subathus in British Garhwal.[1] Purple slates that he had previously mapped as belonging to his 'Purple Slate' series[2], he later found were metamorphosed nummulitics. Griesbach [3] working in the Hundes wrote as follows:—

'the nummulitic rocks of Hundes (north of Niti) have in large measure been converted into a semi-crystalline formation, which one would naturally identify with some of the lower palæozoics (haimantas) which they resemble, were it not that on the one hand their position between the cretaceous and the younger middle tertiaries and on the other, indistinct traces of *nummulites*, determined their geological age accurately'.

Griesbach assigns this particular metamorphism to the abundant basic eruptive rocks found in the Hundes. The parallelism with the phyllitised Subathu rocks of Dadahu and in British Garhwal is perhaps remote, although east of Dadahu there have been found a large number of sheared basic leucophyres. Since, in general, basic rocks do not effect much change on the adjacent sedimentaries, it is possible that the metamorphism of the Nummulitics at Hundes, as well as along the Himalayan foothills, may be only indirectly connected with the associated igneous rocks. Both metamorphism and intrusion may have originated from the same causal stresses.

Distribution in Space.

Regarding the rocks of the Krol Belt in relation to neighbouring zones, the following divisions may be made out:—

(1) *Schist zone:* to the north-east; showing phyllites, schists often with index minerals; recrystallised quartzites; *epi*- and *meso*-conditions.

(2) *Krol Belt:* great variation in character of metamorphism; typically of *epi*-type.

(3) *Zone of Tertiary rocks*: to the south-west; generally non-metamorphosed, but locally indistinguishable from *epi*-type rocks of the Krol Belt.

[1] *Mem. Geol. Surv. Ind.*, XXIV, p. 72, (1890).
[2] *Rec. Geol. Surv. Ind.*, XX, p. 33, (1887).
[3] *Mem. Geol. Surv. Ind.*, XXIII, p. 45, (1891).

This division into three zones is not absolute. Rocks of *epi*-type occur in all three zones. Further, along the Krol Belt, there is longitudinal, or strike, variation in intensity of metamorphism. The Infra-Krol and Krol A stages become more altered towards the south-east.

Discussion.

The metamorphic condition of these rocks is of interest in two connections, firstly, the bearing it has on correlations, secondly, the question of its cause.

One of the arguments used by Pilgrim and West in connection with abolishing the original correlation made by Medlicott of the rocks at Simla with those at Solon was based on the different metamorphic condition of the rocks of the two areas.

Referring to the Simla slates, Blaini, Infra-Krols and Krol limestones, they state on page 6:—

'It is a noteworthy fact that none of the rocks so far mentioned is truly metamorphic. Not only are there no secondary minerals developed, but further, the Simla, Blaini and Infra-Krol series, though containing rocks often resembling slates, have no slaty cleavage and we have found no evidence of any planes of crushing which do not coincide with the planes of bedding; neither is there any crystalline structure or evidence of flow in the limestones; while the Krol sandstone is obviously not a metamorphic quartzite.'

They intended to emphasise the different grades of metamorphism between the Simla and Solon rocks, concluding (1) that the more metamorphosed rocks were the older; (2) that juxtaposition of rocks of different degrees of metamorphism must be accounted for by thrusts, that had brought rocks of different ages into abnormal association.

Had one's attention been confined to the generally unaltered rocks of the Tertiary zone, or, as was that of Pilgrim and West, to the schist zone, the occasional presence of more or of less altered rocks would not have upset the broad impression of constancy in character gained from these areas as a whole. Occasional traverses from either of these areas across adjacent zones would doubtless suggest a contrast sufficient to permit the belief in differences in kind between them. Work along the Krol Belt has shown, however, its transitional character to the zones that border it, and there has proved to be far less conviction as to the rigidity of distinction, both correlative and metamorphic, of the rocks of the three zones.

As seen from the general statement made above, the criteria assumed in the quotation just given are not valid. Viewing the

rocks of the Krol Belt as a whole, there is in many places an approximation to the metamorphic grade of a considerable quantity of the rocks found in the area described by Pilgrim and West.[1]

The contrast between the garnet- and staurolite-schists of the Jutoghs with the shales of the Infra-Krols near Solon is undeniably great, but it must be recognised that this is the extreme contrast. Elsewhere the rocks of the Krol Belt become more metamorphosed, while the Jutoghs, away from the influence of the Chor granite, tend to lose their index minerals. The Jaunsars of the Krol Belt and the Chails of the area mapped by Pilgrim and West are in some places practically indistinguishable, as on Rigana Dhar and at Tikar.

It is not intended to imply that a correlation between the rocks at Simla and Solon should be reverted to, or that thrust-planes are not present. Pilgrim and West found definite structural features, indicative of the existence of thrust-planes, particularly at the base of the Chails. In the Deoban area, Mr. West has recently found mylonites below the Chail thrust.[2] Moreover, these authors obtained evidence of elimination of beds by overlap, which coincided with these structural features.

It is, hoped however, to indicate that the differences between the rocks of the Krol Belt and of the adjacent north-eastern area are not absolute, and that the question of age cannot satisfactorily be told by considering solely their metamorphic aspect.

Gradation.

There is a large body of opinion amongst geologists, championed by Gregory[3] and Kober[4], that all extensive areas occupied by crystall-

[1] It should be expressly pointed out that the criteria they assumed were valid for the few sections in the Krol Belt that they visited. That it has been found that these criteria do not hold, is solely the result of working in detail over a larger area than they were able to visit.

[2] *Rec. Geol. Surv. Ind.*, LXV, p. 130, (1931).

[3] 'Structure of Asia', p. 7, (1929). 'General Stratigraphy', p. 7, (1931).

[4] Kober may be quoted. His claim is that *kata*-rocks (*hypo*-rocks of Fermor) of regional extent, have only been found for certain in the pre-Cambrian. He accepts that *meso*- and *epi*-rocks have been formed as a result of the Mesozoic and Tertiary alpine tectonics. In 'Das alpine Europa' (Berlin, 1931), p. 18, he states:—

> 'Eine einheitliche junge alpine Metamorphose geht über die Metamorphiden des alpinen Orogens hinweg. Kristalline Schiefer der mittleren Tiefenstufe entstehen in regionaler Metamorphose. Diese ist Bewegungsmetamorphose (Dynamometamorphose), auch Belastungsmetamorphose. Wahrscheinlich werden diese Zonen schon vor der Oberkreide von den grossen Schubmassen der Zentraliden überschoben, gelangen so in die Tiefe des alpinen Troges.'

On pp. 268, 274, he suggests that the alpine *meso*-metamorphism may pass to *kata*-type in depth.

See also Kober, 'Der Bau der Erde', 2 Aufl., p. 79, (1928).

ine schists must be pre-Cambrian. This is in contrast to the views of many Alpine geologists, including F. E. Suess, Argand and Staub. Analogies of the Himalaya with the Alps may perhaps be considered too remote, but we may take examples from the Himalaya themselves, to show that the relation between areas of schists and of less altered slates and phyllites, for which there is no reason to suppose a pre-Cambrian age, is often intimate.

Dr. A. M. Heron [1] has described the relation of Triassic and Jurassic rocks north of Mount Everest to their metamorphosed equivalents actually on the mountain-side. A series of shales and limestones, Triassic and Jurassic in age, has been permeated with tourmaline-granite which has metamorphosed them to mica-schists and banded calc-silicate rocks. He writes :—

'In the above-described sections the change from sedimentary to metamorphic rock is very clearly seen, taking place gradually in magnificent cliff faces with no break nor discordance in the stratification ; from a short distance away it is indeed often impossible to say whether one is looking at limestone or calc-schist.'

Hayden [2] criticises Griesbach's assignation of the latter's *Vaikrita system* to the pre-Cambrian on the grounds that similar rocks are found in the Sutlej valley and the Spiti river which should be regarded as Haimantas. He states in regard to these localities :—

'the kyanite-schists and garnetiferous mica-schists are found to pass horizontally into less altered phyllites and clay-slates belonging to the cambrian system and corresponding to Mr. Griesbach's middle haimantas. Similarly, highly altered staurolite and kyanite schists are found between Asrang and Pangi, where the intrusive biotite granite is found in contact with the cambrian slates.'

Coming closer to the area with which we are directly concerned, to the schists associated with the Dudatoli granite, Middlemiss states[3] :—

'I may here emphasise two points—first, the schist found near the gneissose granite is entirely a thorough crystalline schist, a fact needing no microscope to demonstrate ; and secondly, along a line of country, where rock is exposed at every step, it is seen that this culminating intense form *graduates* into a wide-spread less intense form, and that in turn *graduates* into ordinary slates and quartzites.'

Finally may be quoted Mr. D. N. Wadia's description of the rocks in the Hazara [4] area, of late pre-Cambrian and of Cambrian age.

'There is not much doubt that by far the largest part of the schist zone of Hazara and Karnah represents regionally as well as thermally altered Dogra (Hazara)

[1] *Rec. Geol. Surv. Ind.*, LIV, p. 223, (1922).
[2] *Mem. Geol. Surv. Ind.*, XXXVI, p. 9, (1904).
[3] *Rec. Geol. Surv. Ind.*, XX, p. 137, (1887).
[4] *Op. cit.*, LXV, p. 200, (1931).

slates. Middlemiss .... entertained no serious doubt as to their identity. The perfectly uniform and unvarying argillaceous composition of Dogra slate from place to place, save for the ubiquitous dolerite dykes and rare thin limestone layers, is one unfailing criterion. In the present area, it is permeated with granitoid gneiss intrusions (Central Himalayan gneiss), and the contact effects on the slates, converting them into phyllites, hornfels, and thinly foliated garnetiferous biotite-schists, with occasional staurolite, round the larger intrusions, are well seen.'

Three facts are evident from these accounts. Firstly, schists over extensive areas may be of Palæozoic, or even later age, an opinion that is held by most alpine geologists. Secondly, these schists grade into slates, phyllites and limestones, of types prevalent throughout the geological succession in the Himalaya. Thirdly, the intense, schist form of alteration is related in all cases to the intrusion of granite; while the less intense, phyllite and slate, forms of alteration are connected with the general regional stresses operative at the time.[1]

Besides the lateral variation in metamorphic intensity described in the quotations given above, there is also variation in dip section. Rocks of markedly different metamorphic aspect may be seen to be interbedded, and in such a close manner that their juxtaposition cannot be explained by thrusting or by isoclinal folding of distinct rock series.

Metamorphism of low-grade, *epi*-type, and approaching *meso*-type, appears to be selective, being greatest, in the same locality, in those rocks that were presumably richer in unstable minerals, or had a higher water content. It is only in the highest grades that external influences are intense enough to overcome small differences between beds of approximately the same facies, and bring all the rocks to a common level of reconstruction.

Position and age of granites.

It is a singular feature that the Dudatoli and Lansdowne granites occur synclinally at the top of a synclinal succession of slates and schists. The same relationship may obtain with the Chor granite. It is not at all improbable that, since the great series of Jutogh

Granites in cores of synclines.

[1] These accounts would appear to militate against any suggestion that thrusts separating rocks of dissimilar metamorphic grade had been missed by the observers. The stress laid upon continuity of exposures shows that the observations were critical, and the whole trend of these author's accounts disposes of the possibility that the wish was father to the thought, in describing this gradation.

rocks at Simla occurs in synclinal form, they may have originally been capped by a continuation of the Chor granite, and may have owed much of their metamorphism to a granite which has now been removed. Oldham [1] postulated this, but the view has since been discarded[2], on the grounds that an intrusive mass is not capable of producing wide-spread metamorphic effects, such as are found in the Jutoghs. The occurrence of these gneissose granites in the cores of synclines certainly demands some connection of the granite with the general processes of regional metamorphism. It is probably nearer the truth to picture both the intrusion of the granites (or their self-generation, 'inborn', so to speak, in the cores of the folds[3]) and the general regional metamorphism as part effects of a wider cause.

Age of granites.

I have given reasons elsewhere [4] for believing that some of the gneissic granites of the outer Himalaya were Carboniferous or slightly older, and were connected with tectonic activity along the Aravalli axis. Further, since the Hazara granite intrudes the Dogra slates, which are pre-Cambrian and Cambrian in age, it is permissible to regard this granite as post-Cambrian. The general similarity in character and manner of occurrence of the Hazara, Chor, Lansdowne and Dudatoli granites suggests that their correlation is permissible, and that they were intruded during the Palæozoic era. The evidence, which is not absolute, is discussed in the paper quoted.

Difficulties arise if an attempt is made to narrow down the time limit still further. The Jaunsar arkoses indicate the presence of an earlier granite, but the Jaunsars are affected by the same Aravalli orientation that is seen in the Lansdowne granite. This orientation in the Lansdowne granite may presumably be connected with its intrusion tectonics. It is tempting, therefore, to regard the intrusion of the granite as immediately post-Jaunsar (? post-Devonian) in age, since both granite and Jaunsars are affected along the same tectonic directions. As opposed to this reasoning, it is possible to assume rejuvenation of activity along the Aravalli axis, and to object that similarity of orientation is not proof of tectonic contemporaneity.

[1] *Rec. Geol. Surv. Ind.*, XX, p. 148, (1887).
[2] *Mem. Geol. Surv. Ind.*, LIII, p. 8, (1928).
[3] This is not the place to enter into a discussion on the formation of granites. It must suffice to say that the appearances in the field do indeed suggest that simple intrusion from some totally foreign source is not a complete explanation of some of these occurrences of granite. Compare Middlemiss, *Rec. Geol. Surv. Ind.*, XX, p. 140, (1887).
[4] *Rec. Geol. Surv. Ind.*, LXVI, pp. 461-471, (1933).

Application to Krol Belt.

In the Hazara area, Mr. Wadia has the following succession[1] :—

Cambro-Silurian.

Dogra slates (Cambrian and pre-Cambrian, and probably equivalent to the Simla slates).

Salkhala series (Archaean).

Wadia and West[2] are agreed that the Jutoghs of the Simla area are equivalent to the Salkhalas of Hazara. The Jutoghs must therefore be regarded as Archaean.

Mr. West[3] has related the higher grades of metamorphism of the Jutogh series to the intrusion of the Chor granite. It is known also that the Dogra slates owe their metamorphism to the Hazara granite. It follows that, besides the Archaean formations, which perhaps were schistose before the intrusion of the gneissic granites, there was a later, post-Cambrian, development of schists which was directly connected with these intrusions.

We have, therefore, to consider the regional metamorphism of the Dogra slates, and possibly also some of the metamorphism of the Jutoghs, as Palæozoic. We know also that the Krol, Tal and Tertiary rocks have been metamorphosed as a result of the Tertiary orogenic movements. Four factors must therefore be disentangled :—

(1) The possible existence of Archaean schists, of *meso*-type.
(2) The broad regional metamorphism of the Palæozoic sediments, of *epi*-type.
(3) The locally intenser grade of this metamorphism in association with gneissic granites, of *meso*-type.
(4) The later metamorphism resulting from the Tertiary orogenic movements, of *epi*-type:
   (*a*) acting on Palæozoic sediments already affected by the earlier metamorphism;
   (*b*) acting on Infra-Krol, Krol, Tal (late Palæozoic and Mesozoic) and Tertiary sediments, which had not been deposited at the time of the earlier metamorphism.

[1] *Rec. Geol. Surv. Ind.*, LXV, p. 202, (1931).
[2] *Op. cit.*, p. 126, (1931).
[3] *Mem. Geol. Surv. Ind.*, LIII, p. 60, (1928).

Nature of Tertiary metamorphism.

The effects of the Tertiary movements on Infra-Krol, Krol and Tal sediments has been to cause slaty cleavage, the formation of phyllites and locally of sub-schistose rocks. Limestones have flowed and recrystallised, and quartzites have been permeated with vein quartz. The effects have been such that slates in the Infra-Krol are similar to some in the Simla and Jaunsar series, and may even be confused with sub-schistose rocks in the Chails. Tals resemble Jaunsars, not only lithologically, but also in metamorphic aspect. Krol A slates resemble green slates in the Jaunsars. Phyllitised Subathu shales may be confused with rocks in the Infra-Krol and Jaunsar series.

It is seen that sediments deposited after the regional Palæozoic metamorphism have to a large extent attained the same physiognomy as those that have undergone both the earlier, Palæozoic, and the later, Tertiary, metamorphism. *Epi*-conditions prevailed throughout. The superposition of a later *epi*-metamorphism on an earlier metamorphism of the same type has had no additive effect.

No granites were intruded amongst the rocks of the Krol Belt. Granites and *meso*-grade schists occur only in the zone to the north-east of the Krol Belt.

Evidence of pebbles in conglomerates.

It is of interest, therefore, to see whether the rocks of the Krol Belt give any information as to the previous existence in this neighbouring zone of rocks of higher grade, *meso*-type metamorphism. Conglomerates are common throughout the geological succession in the Simla-Chakrata hills. Evidence should be obtained, by examining the boulders and pebbles, whether any high-grade metamorphic rocks were exposed to denudation, or were formed at all, prior to the deposition of the rocks containing the pebbles.

It is a striking fact that, except in one rock slice of the Blaini boulder bed, no single instance has been found either in the field, or in rock-slice, of any true schists or metamorphic rocks of *meso*-type being included in the pre-Tertiary conglomerates. Phyllites, black (? carbonaceous) slates, and sandstones are found abundantly as fragments in the Simla slates, the Morar-Chakrata beds (largely Simla slates), and the Blaini ; but never schists, never garnets, and only one case of a completely recrystallised mosaic-quartzite (slice 21999). The boulders in the Blaini are almost entirely dark slates, sandstones and quartzites, all types which can be matched

in the Simla slates and Jaunsars. The boulders in the Jaunsars are mostly of material derived from penecontemporaneous erosion, while the abundant pebbles of vein-quartz perhaps indicate a granite-pegmatite source. In the Jaunsar arkoses are found plagioclase felspar and tourmaline. In the Tal arkoses occur microcline and tourmaline. The provenance of these minerals was almost certainly granitic.

Pebbles of gneissic granite, similar to the Hazara granite, have been noticed by Mr. Wadia in the Agglomeratic Slate of Kashmir, *i.e.*, in rocks of Upper Carboniferous age. A pebble of albite-oligoclase-granite has been found in the 'volcanic breccia' of Garhwal, which is either Carboniferous or pre-Carboniferous in age.

Aside from these indications of the existence of granites, there is extremely scanty indication of any derivative environment to the whole sequence of rocks in the Krol Belt other than that showing *epi*-metamorphism. Not until the Dagshais, of Oligocene or Miocene age, are there found metamorphic rocks and minerals of *meso*-type. In the Dagshais and Kasaulis, garnet is abundant. In the Sutlej rocks, garnet and pebbles of recrystallised quartz-schist may be found.

Professor F. E. Suess.

A similar feature has been noticed by Prof. F. E. Suess[1]. He has been criticised, amongst others by Gregory[2], for supposing that the schists and gneisses of Moldanubian type in Bohemia are equivalents of Barrandien Palaeozoic sediments, metamorphosed by the Hercynian revolution. Referring to the non-metamorphosed pre-Cambrian and early Palaeozoic equivalents of Central Bohemia, he states :—

'Conglomerates and graywackes in which crystalline constituents are entirely wanting are rather rare. But a geologist rambling over the huge stretches of the Algonkian and early Cambrian of Bohemia will be deeply impressed by the fact that the innumerable beds of conglomerate consist exclusively of pebbles of slate, lydite, diabase, spilite, and a few others from the Algonkian itself in astounding monotony, and that crystalline constituents are entirely absent. It appears almost as if at that time no other kind of rocks had been in existence.'[3]

[1] *Geol. Mag.*, LXIX, p. 431, (1932).

[2] 'Dalradian Geology', p. 24, (1930).

[3] I may perhaps be excused in quoting from my own Progress Report, p. 29, for 1931, where less graphically and less clearly expressed, I wrote :—'There is as well a total failure of any fragments of schist in the boulder beds and conglomerates of the rocks so far seen, as if the periods of metamorphism post-dated the formations of the succession.' The impressions gained in the two cases are so strikingly similar that they deserve recording, because of their independent formulation.

This evidence anomalous.

The facts as related to the Himalayan area present anomalies. The absence of pebbles and boulders of schist and metamorphic quartzites in the Simla and Jaunsar series would seem to indicate either that no area of metamorphic rocks of *meso*-type was exposed to denudation at the time of deposition of the sediments, or that metamorphism of *meso*-type had not then occurred. Yet there is evidence in the Carboniferous boulder beds that granites had intruded previously. Moreover, the pebbles of gneissic granite in the Agglomeratic Slate suggest the previous intrusion of precisely those granites that were associated with the regional metamorphism of Dogra slates. If gneissic granites are found as pebbles, it might be expected that schists would also be found. It is true, as Mr. Wadia has suggested to me, that schists would readily disintegrate during transportation, but at least index minerals, such as garnet, should occur in the sediments derived from the schistose areas.[1]

The existence of post-Cambrian granites to some extent explains the difficulty, since the formation of schists with higher grade index minerals would have been entirely subsequent to the deposition of the Simla and probably the Jaunsar series. Even so, the boulder beds, such as the Agglomeratic Slate, the Blaini, and the 'volcanic breccia' of Garhwal, should contain rocks with metamorphic aspect, since they were presumably formed after metamorphism of the rocks, or equivalent rocks, from which they were derived.

It must be assumed that the zone of granite intrusion prior to the altogether later Tertiary thrusting, was far removed from the rocks now found in the Krol Belt. The Carboniferous boulder-bearing rocks must have been derived locally from rocks of low-grade metamorphism in the Simla and Jaunsar series, with only occasional stray pebbles of resistant granite derived from the zone of granite intrusion. Even in Kashmir, where the Agglomeratic Slate was evidently closer to the area of granitic intrusion, Middlemiss[2] mentions only the following pebbles :—quartz, feldspar, slate,

[1] De Terra ['Geologische Forschungen im westlichen K'un-lun und Karakorum Himalaya' Berlin, p. 45, (1932)] notes the following rocks to be present as pebbles in the basal conglomerate of the Kilian series (Old Palæozoic) in the K'un-lun :—gneiss, chlorite-quartz-schist, mica-schist, and vein-quartz. He remarks that the conglomerate is locally coloured red on account of the oxidation of biotite in the pebbles of mica-schist, thereby emphasising the detrital occurrence of this rock type. The provenance of these pebbles is from the Karakasch series, which is probably pre-Cambrian.

[2] *Rec. Geol. Surv. Ind.*, XL, p. 233, (1910).

quartz-porphyry, occasional quartzite, pegmatite and tourmaline-granite.

Archaeans must have formed a basement and margin to the area of deposition of the Simla slates, but they have left no recognisable traces of the characters they now exhibit. Possibly they occurred then as phyllites rather than as schists.

IX. MANDHALIS.

Significance of Boulder Beds.

The Mandhali beds have offered a problem of great difficulty. Allusion has already been made to them on pages 368 and 396. The previous workers concerned with this group of rocks are Oldham (1883-1888), Pilgrim and West (1928), and West (1931). In 1888, Oldham summed up their characters as follows[1] :—

'The group....is of the most protean character, consisting of quartzites, slates, limestones, conglomerates and boulder beds in most variable proportions and interstratified in the most extraordinary manner; it being not uncommon to find slates or even limestone interbedded with coarse grits or conglomerates. This variability appears to be due to the fact that it has been deposited in close proximity to land, and always contains a large proportion of debris derived from the older rocks of the neighbourhood. Thus in Northern Jaonsar and Bawar, where it rests on the Deoban limestone fragments of that rock are extremely abundant in it and there are several beds of a conglomerate composed exclusively of rounded boulders of the Deoban limestone imbedded in a matrix of the same rock in a finely comminuted form, while in Southern Jaonsar, where it rests on the quartzites of the Jaonsar series the group consists almost entirely of coarse quartzites and grits.

But the great characteristic of the Mandhali group is the presence of boulder beds of the same type as that of the Blaini group. So great indeed is the similarity that in more than one case an exposure of this group has been described as Blaini.'

Oldham finally correlates these beds with the Blaini.

With this correlation, Pilgrim and West are in agreement, although, on account of the thickness of the Mandhalis, these authors were inclined to regard them as equivalent to the combined Blaini and Infra Krol.[2]

[1] *Rec. Geol. Surv. Ind.*, XXI, p. 136, (1888).
[2] *Mem. Geol. Surv. Ind.*, LIII, p. 43, (1928).

There are three distinct rock facies which have to be considered in a discussion of the Mandhalis :—

(1) Limestones.
(2) Pebble beds and conglomerates.
(3) Boulder beds.

Most prominence has been given to the boulder beds, the presence of which has led to the correlation of the Mandhalis with the Blaini. The associated limestones, pebble beds and conglomerates have been variously grouped with the Mandhalis, Jaunsars and Chails according to the impressions gained from single exposures, where one or other or all of the above facies are prominent.

It is true that boulder beds are striking rocks which at once attract the eye. Moreover, the origin of these boulder beds, whether glacial, volcanic or otherwise, is certainly one that implies somewhat abnormal conditions of sedimentation. In proportion to this abnormality of origin, it may be thought that the causal factors would be rarer. Consequently, a series of boulder beds, with an abnormal manner of origin, might be considered to be probably contemporaneous.

This was the basis of the reasoning of Oldham, who wrote as follows[1] :—

> 'If we take the glacial origin of the two as proved, this in itself would establish the contemporaneity of the two groups of beds which outside evidence places between the Deoban and the upper part of the carbonaceous system.'

The premises do not appear to me to be sound. In New South Wales, Australia[2], there are five glacial horizons between the Upper Carboniferous and the Upper Permian. During the Pleistocene glacial period of the European Alps, there were four periods of glaciation, separated by interglacial periods.

Oldham himself, on pages 132 and 133 in the same paper just quoted, seemed satisfied, in spite of a certain element of doubt, that two exposures of boulder-bearing rocks did properly occur low down in his Jaunsar succession.

I have mentioned the occurrence of boulder beds in the Nagthat beds on page 373. In Garhwal I have noticed a boulder bed in the middle of Middlemiss's Purple Slate series[3], which occurs above and is quite distinct from, the 'volcanic breccia'.

[1] *Rec. Geol. Surv. Ind.*, XXI, p. 137, (1888).
[2] 'Explanatory Notes to New Geological Map of Australia', Table E, p. 62, (1932).
[3] *Rec. Geol. Surv. Ind.*, XVIII, p. 74, (1885); *op. cit.*, XX, p. 34, (1887).

In the Hazara area, Mr. Wadia has found a conglomerate, 120 feet thick, which occurs above the Dogra slates (=Simla slates) and at the base of a series of phyllites and quartzites, called the Tanols.[1] At the top of the Tanols near Talhatta, is another conglomerate, possibly equivalent to the Blaini.

The following correlation is suggested :—

Hazara.	Simla-Chakrata hills.
Talhatta conglomerate	Blaini.
Tanols	Nagthat and Chandpur stages.
Conglomeratic boulder bed	Mandhali stage.
Dogra slates	Morar-Chakrata beds (Simla slates).

Boulder beds may be formed under very varied conditions. Middlemiss assigned a volcanic origin to the breccia in Garhwal. This is exactly similar in appearance to the Blaini boulder bed, which has been regarded as glacial. Later, when working in Kashmir, he was unable to decide whether the Agglomeratic Slate was of glacial or of volcanic origin. Mr. Wadia has recently found traces of original glass in this Agglomeratic Slate and concludes that it is probably volcanic.[2] The intimate association of glacial and volcanic rocks is well displayed in the Permo-Carboniferous succession of New South Wales.

We should expect every gradation between true tillites, fluvio-glacial beds and 'ordinary' conglomerates. Certainly in the case of the Mandhali and Blaini boulder beds, conglomerates can be seen to grade into boulder beds. Further, the tuffs associated with the Chandpur beds prove definitely that volcanic activity occurred, and at a time, in my opinion, between the deposition of the Mandhalis and the Blaini. It is quite possible that agglomerates may have been formed earlier and later than the tuffs, contemporaneously with the supposed glacial tillites.

On the grounds, therefore, both of origin and of frequency, it cannot be asserted positively that the boulder beds of this region are necessarily glacial, and necessarily of one period.

I can offer no absolute proof that the view previously held, namely, that the boulder beds are glacial and all Blaini, is erroneous, because the sections now exposed are disturbed, and by themselves do not permit of certainty. But this former view has led to difficulties.

[1] *Rec. Geol. Surv. Ind.*, LXV, pp. 204-206, (1932)
[2] *Mem. Geol. Surv. Ind.*, LI, p. 235, (1928).

Consequences of Mandhali-Blaini Correlation.

If the correlation of the Mandhalis with the Blaini is accepted, two difficulties are at once evident:—

(1) The Mandhalis south of Chakrata appear everywhere to dip synclinally below the Jaunsars, and are, therefore, on this supposition, overlain by rocks older than themselves. The whole syncline of Jaunsars, normal Blaini, Infra-Krols, Krol limestones and Tals must rest as a thrust mass, or *nappe*, upon the Mandhalis.

(2) There must be two totally distinct facies of the Blaini now in close proximity:

(*a*) the thin boulder bed and limestone, which runs from Chandpur peak to Shiwa Kalan;

(*b*) the extremely complex series of beds called Mandhali.

Reasons against Mandhali-Blaini Correlation.

There is no sign of the thrust plane that would be required to separate the Mandhalis from the overlying Chandpur beds, if the Mandhalis and the Blaini are regarded as equivalent. The quartzite associated with the Bansa limestone is, it is true, often markedly schistose, but not more so than many of the quartzites in the Mandhalis themselves and in the Nagthat stage. Thrust planes are admittedly often very difficult to locate, since they may leave little trace of their action in the rocks brought into abnormal juxtaposition. It seems irrational, however, to assume a thrust solely because of a lithological change from a series of limestones, phyllites, quartzites and boulder beds up to a series of banded quartzite and phyllites, with tuff beds, unless the ages of these contrasted rocks are known. It has just been argued that boulder beds are a common feature in the Himalaya and that age cannot be told from their occurrence.

The associations of the Mandhali and Blaini rocks may be summarised as follows:—

(1) *Mandhali.*—Characterised by a complex association of dark limestones, often sandy, and often marmorised, phyllites, grits, boulder beds, conglomerates, schistose quartzites, apparently underlying the Chandpur stage. Boulder beds full of limestone fragments and limestone of *in situ* growth.

(2) *Blaini.*—Pink siliceous limestone, not sandy, associated with boulder bed in which limestone fragments are very rare. The limestone and

boulder bed, if both present, are always together. Overlies the Nagthat beds, which in turn rest on the Chandpur stage.

This Blaini boulder bed, with its pink siliceous limestone, is always overlain by Infra-Krol and Krol rocks, the three stages forming the only readily recognisable sequence in the whole of the Krol Belt. East of longitude 77° 30′, the Tal beds form an additional and also distinctive series above the Krol limestones, the sequence eastwards invariably being Blaini: Infra-Krol: Krol: Tal.

This Blaini: Infra-Krol: Krol: Tal succession is 'normal' in the sense that it is almost certain that the stages in it are in their original order of deposition, and are unaffected by thrusts of any regional magnitude. It may be taken as the standard of reference for the Krol Belt. The relationships between the various stages in it are constant, and their mapping, apart from physical exertion, is always easy.

Contrasted with this orderly sequence, of which the Blaini is the invariable basal member, is the disorder that prevails amongst the Mandhali rocks, and the fact that the Mandhalis are overlain by a group of rocks totally distinct from the Infra-Krol to Tal succession.

Since, then, we find that the Mandhalis, in the region where the whole of the geological column is best developed, occur in an association that is altogether foreign to the Blaini and overlying rocks, we may conclude that the Mandhali-Blaini correlation is probably unsound.

Apparent support for the Mandhali-Blaini correlation is found along the tract bordering the Krol thrust. Here both the Chandpur and the Nagthat stages are almost absent, and Blaini and even the Krol are brought into contact with Mandhalis, causing admitted embarrassment. But the tract bordering the Krol thrust is so clearly a zone in which thrusts are common and abnormal juxtapositions occur, that it can hardly be considered reasonable to consider only the evidence of such a tract, when fuller evidence is to be obtained further north.

Field Relations to North-West.

At the time of mapping the outcrops north of the Giri river, I had not seen the Mandhalis. The sections showed that a series of thin-bedded limestones and dark slates, with some soft green slates, passed up to the Bansa limestone and then into Jaunsars of Nagthat type. Boulder beds were found sporadically at the

base of the succession. The occurrence of limestones did not seem anomalous, since they had been seen elsewhere in the Jaunsars, and accordingly the whole sequence was regarded as Jaunsar. The boulder beds were mapped as Blaini, and were considered to have been thrust over by the Jaunsars. Later, on acquaintance with the Mandhalis, it was realised that the beds low down in the sections were probably Mandhali. To what extent the boulder beds in the eastern part of sheet 53 J/10 are Mandhali, and to what extent Blaini, is altogether uncertain since at that time, I had not learnt to know the features which differentiate these boulder beds. An attempt has been made to mark the approximate extent of the Mandhalis by stippling. A definite boundary with the Jaunsars cannot be drawn.

In the neighbourhood of Dadahu, a complex association of Infra-Krol slates and Blaini boulder beds has been overthrust by the Jaunsars and Mandhalis. Bleaching slates of Infra-Krol type occur also in the Mandhalis, and it may be objected that, near Dadahu, Mandhali slates and boulder beds have been mistaken for Infra-Krol and Blaini. The beds mapped as Infra-Krol are overlain by Krol limestones on hill 3,619 feet, and continue to the north-west for 40 miles along the strike, always overlain by Krol limestones, and always associated with Blaini boulder beds and limestone. It is not likely therefore that they have been incorrectly mapped near Dadahu. Uncertainty only exists between Dadahu and the Tons river, because there slates and boulder beds occur, without Krol limestone, that might be either Mandhali or Blaini and Infra-Krol. This, in my opinion, is no proof that the Blaini, Infra-Krol and Mandhali are the same. It is simply an illustration of the complexity that may arise when similar rock types, whether contemporaneous or of different ages, are brought together by thrusting and unconformable overlap.

One other exposure, at the north-western end of the Krol Belt, may be mentioned. This is an isolated lenticular outcrop of folded and brecciated limestones, together with knotted slate, which occurs at Dhari, near Kandaghat. It was at first regarded rather doubtfully as Krol A, on account of the lenticular folded blue limestones. Since the rocks occur wedged in between Jaunsars and Simla slates, and the limestones are more similar to those of the Mandhalis than to the Krol A limestones, the outcrop may with confidence be mapped as Mandhali.

The limestones at Badgala are of the same type, folded and brecciated.

Conclusions.

The argument relating to the position of the Mandhali rocks is based on the following points:—

(1) In south Chakrata, a thick series of Mandhali rocks appears to pass normally upwards into the Chandpur stage of the Jaunsar series. No trace of a thrust plane is seen. The boundary chosen between the two stages is one of convenience, *viz.*, at the top of the Bansa limestone.

The undoubted Blaini, on the other hand, which in this region consists solely of a boulder bed and an overlying pink siliceous limestone, passes up into the Infra-Krol: Krol: Tal succession, which is the type succession for the Krol Belt.

(2) In the Kandaghat area, Simla slates appear to grade upwards into Jaunsars. Boulder beds and pink limestone sometimes intervene, which admittedly are identical to those in the Blaini. At Dhari, near Kandaghat, occur brecciated limestones, of Mandhali type, between the Jaunsars and the Simla slates, so that the parallel with Chakrata area is moderately close.

(3) Boulder beds definitely occur in the Nagthat rocks that are quite distinct from the Blaini. The occurrence of other boulder beds, in the Mandhalis, need not therefore occasion surprise and lead to the deduction that they must inevitably be Blaini. This is supported by occurrences of boulder beds at more than one horizon both to the north-west and to the south-east of the Krol Belt. Boulder beds are not rare in the Himalaya, either in space or in time. Their manner of origin is not everywhere the same. It cannot be argued that in the Simla area similarity implies contemporaneity or even identity in manner of origin.

It was stated on page 397, that the Blaini between Simla and Badgala may in reality be Mandhali. The conclusions reached here may somewhat simplify the structure of the Simla-Chakrata area, since they would eliminate the necessity of a thrust at the base of the Jaunsars.

Mr. West has found the Mandhalis of northern Chakrata to grade downwards into Deoban limestone, fragments of which they contain.[1] This same Deoban limestone rests on the Jaunsar series, while, in the Beshair and Gutu Gads, Jaunsars are found as well above the Deoban limestone.

The occurrence of Deoban limestone normally below the Mandhalis does not affect the argument given above, because the Mandhalis south of Chakrata are probably thrust over the Morar-Chakrata

[1] *Rec. Geol. Surv. Ind.*, LXVI. pp. 128-129, (1932).

beds (Simla slates). If the interpretation given in this paper be correct, the position of Jaunsars below the Deoban limestone must be due to a thrust.

X. CORRELATION WITH MUSSOORIE AND GARHWAL.

In 1933, mapping was continued eastwards, past Mussoorie. In July and October, 1932, short visits were paid to Lachmanjhula and Lansdowne in British Garhwal. The Garhwal area was mapped by Middlemiss in 1885-1887.[1]

Mussoorie (Sheet 53 J/3).

The Blaini: Infra-Krol: Krol: Tal sequence reappears south-east of the Jumna river and has been traced eastwards to longitude 78° 15′. The series of this sequence occur in synclinal form, with the axis of the syncline running N. W.-S. E. just north of Landour cantonment. On the north side of the syncline, the Blaini rests on the Nagthat stage of the Jaunsar series. The south side has not been examined in detail, but it evidently presents the same difficulties, on account of unconformable overlap and extensive thrusting, as have been experienced along the Giri river.

The series of this sequence are typically developed and are unmistakable. Upper Krol limestones make up the whole of the Mussoorie ridge from Banog to the Landour bazar. Krol E limestone is well seen just opposite Stiffles' cocktail bar. Landour cantonment is built on lower and upper Tal rocks, which extend along the Mussoorie-Tehri mule-track as far as mile 5.

A distance of 18 miles still remains in order to join up with the mapping of Middlemiss. That the rocks of this sequence will continue into Garhwal is evident from the brief traverses made at Lachmanjhula and Lansdowne.

Lachmanjhula (Sheet 53 J/S. W.).

The area between Lachmanjhula and Bijni is not favourable for seeing outcrops, owing to thick jungle. Between Lachmanjhula and mile 18 (on the Hardwar-Badrinath pilgrim track), there are black, carbonaceous, slaty shales and silty limestones, similar to the combined Krol A, Infra-Krol rocks east of Dadahu. By mile 18

[1] *Rec. Geol. Surv. Ind.*, XX, p. 33, (1887).

occur banded, green, calcareous slates, very characteristic of the Krol A stage. Along the pilgrim route near mile 19, and on the path from Lachmanjhula to Bhadsi (30° 06′: 78° 21′), between aneroid heights 1,900 and 2,500 feet, there are seen red shales identical to these in the Krol B, Red Shale, stage. Massive, cream-white, 'pseudocoralline' limestones occur in the stream three-quarters of a mile up from Gattugad Chatti (30° 05′: 78° 23′). These are identical to the Krol E limestones (specimen 43·766) found in the ravine one-third of a mile E. S. E. of hill 5,930 feet (30° 43′: 77° 17′).

The Massive Limestone is followed upwards near Kota (30° 07′: 78° 25′) by well-bedded white quartzites, which cross the Ganges, and occur as dip slopes by Atali (30° 04′: 77° 28′). They are exactly like the Upper Tals of Mussoorie and the area west of the Tons. The equivalent of the Lower Tals in Garhwal appears to be in the carbonaceous shales and sandstones seen at the confluence of the Huinl and Ganges rivers. The white quartzites of the Upper Tals are much thinner near Bhadsi, where they grade upwards into dark, current-bedded calc-sandstones or sandy limestones, sometimes oolitic, and generally crowded with broken fossils.

Medi Gad, near Lansdowne (Sheet 53 K/N.E.).

Exposures may be seen in the Medi Gad, from Raitpur (29° 54′: 78° 42′) to near the Eastern Nayar river. The Tal beds do not show up well. Below them comes a blue, crystalline, massive limestone, exactly like the Krol C. By a small stream half a mile E. N. E. of Raitpur, the massive limestones are followed below by red sheared shales, with blotches of green and occasional dolomitic limestone bands, identical to those in the Krol B stage. Going down the dip come successively:—lenticular dark limestones set in calc-slate, and banded grey and green slates (Krol A), black, banded, carbonaceous slates with salty efflorescences (Infra-Krol), purple mica-slates with subordinate green slate bands, thin limestones; a thin conglomeratic breccia, purple slates, and finally ripple-marked quartzites, strongly veined with quartz. Since Middlemiss draws his boundary between the Massive Limestone and the Purple Slate series exactly at the above-mentioned stream, it is clear that he regarded the red shales and green calcareous slates as part of his Purple Slate series. A suspicion that this was so was

aroused near Lachmanjhula, but the thick jungle there and the intense July heat prevented any detailed examination. In this manner of division, Middlemiss was perfectly justified. The thin calcareous slates (Krol A) of Garhwal clearly have very little in common with the cliff-forming Massive Limestone. Being slates, they would naturally be classed with the Purple Slate series, the more so since red shales occurred above them. This is in contrast to the Solon neighbourhood, where the thin-bedded Krol A limestones occur in cliffs 300 feet high. The change that has taken place in the 120 miles that intervene between Solon and Raitpur, is due more to change in composition than to any demonstrable increase in intensity of stress in the Garhwal area.

The purple slates may belong partly to the Infra-Krol and partly to the Jaunsars. The ripple-marked quartzites, low down in the Medi Gad section, are exactly like those found in the Jaunsars of the Simla-Chakrata area. If this be so, the 'volcanic breccia' of Middlemiss must occur below the Jaunsars, in just the position of the Mandhalis.

Sutlej River Area (Sheet 53 A.).

At the opposite end of the Krol Belt there is a narrow strip of limestone which crops out amongst the Tertiary rocks from Badhota (31° 03′ : 76° 55′) northwards to the Sutlej river, north-east of Bilaspur (31° 20′ : 76° 45′). Good exposures of cherty limestones and interbedded red and black shales of Krol D type may be seen on the path from Bilaspur to Parnali (31° 18′ : 76° 47′). These limestones were noticed by Medlicott[1] and by Pilgrim.[2] Both writers regarded them as Krol.

Conclusions and Table of Correlation.

Adopting the correlation of the Upper Krol limestone with the Massive Limestone of Garhwal, the Krol rocks are seen to extend from the Sutlej river, near Bilaspur, to Gungti Hill (29° 45′ : 78° 55′) in Garhwal, a distance of some 175 miles. The limestones

[1] *Mem. Geol. Surv. Ind.*, III, p. 80, (1864).
[2] Field Diary for March, 1924 (not published).

at Naini Tal are most probably Krol, which would bring the total length of outcrop up to 208 miles.[1]

The following table is offered as a tentative correlation. The correlation with the Kashmir-Hazara area is partly drawn from information supplied by Wadia and West, in the Director's General Report for 1930.[2] It must be regarded as very tentative.

Correlation Table.

	Hazara-Kashmir.	Simla-Chakrata.	British Garhwal.
Oligocene. Eocene	Nummulitics	Subathus	Nummulitics.
Cretaceous	Giumal sandstone	Upper Tal	Tal.
Jurassic	Spiti shales	Lower Tal	Almost absent.
Trias	Trias limestone	? Absent	? Absent.
Permo-Carboniferous.	Infra-Trias limestone and Panjal trap.	Krol E, Krol D, Krol C } Upper Krol limestone.	Massive Limestone.
	Upper Tanawal (Tanol)	Krol B Red Shales; Krol A Lower Krol limestone.	Purple Slates (with occasional boulder beds).
Upper Carboniferous	Agglomeratic Slate; Talhatta conglomerate	Infra-Krol; Blaini	
? Devonian and Silurian.	Lower Tanawal (Tanol)	Nagthat stage	
	Conglomeratic boulder bed	Chandpur stage; Mandhali stage	Volcanic Breccia.
Lower Palæozoic and pre-Cambrian.	Dogra slates	Simla slates——?——	——Schistose series.

Dolerites have been found intrusive into Krol and older rocks and into Tertiaries, but not in Tals. There is possibly a Permian-Krol suite and a later Tertiary suite.

[1] It was stated in *Mem. Geol. Surv. Ind.*, LIII, p. 8, (1928), that the Krol limestone extends to the north-west as far as the Ravi river. This must be an accidental error, occasioned by the title of Medlicott's memoir. Between Bilaspur and the Ravi river, the rocks bordering the Tertiaries are older than Krol. At Joginder Nagar (32° 0′ : 76° 47′), schists, phyllites and quartzites, together with intrusive porphyritic granite, are thrust over the Tertiaries. These are either Jutogh, Chail or Jaunsar. The Krol limestones are definitely absent. The equivalent of the Krol rocks is probably not seen until Kashmir is reached.

[2] *Rec. Geol. Surv. Ind.*, LXV, p. 128, (1931).

XI. TECTONICS.

The most cursory examination of the rocks of the Krol Belt shows their extreme complexity of structure. This complexity is seen in single exposures as well as in broad views. It becomes evident as a result of continued mapping, and may be seen at a glance in a rock-slice.

In places there is such chaos that no rational explanation is possible. Objection may be made to the adjective 'rational'. It may be maintained that with fuller knowledge, or with better exposures in the jungle-covered lower slopes of the hills, the chaos might prove to be apparent, and might resolve itself into structures more readily explicable. To some extent this objection must always hold, but it is less readily applied in describing orogenic areas of the type seen in the Krol Belt. Structure is everywhere seen by eye to be so chaotically disposed that the fear is that the map, however odd, does not adequately show it. For certain tracts bordering the thrust-planes, the only 'rational' explanation is one that does not attempt to simplify at the expense of structure, in favour of readily understandable sections. Such tracts are, therefore, difficult to represent on the map, partly because the scale demands simplification, partly because of an inherent dislike of leaving suspicious loose ends and oddly juxtaposed colours.

No thrusts or faults have been marked on the one-inch maps, since almost every plane separating rocks of different hardness, and every boundary plane between different stages, is a minor or major thrust. The major features have been traced on a separate quarter-inch map, Plate 24. It is these alone that can be here described.

Thrust-bound Synclines.

Broadly speaking, the structure of the Krol Belt is that of two thrust-bound synclines of Krol (in the east, of Krol and Tal) rocks resting on a Jaunsar-Simla slate foundation.

(1) The *Nigali* syncline, named after the magnificent ridge that runs south from near Guma peak. Tal and Krol rocks occur in a wide syncline, with steep northern limb, locally inverted and severed by the Guma thrust. The southern limb is attenuated and founded on the Giri thrust.

(2) The *Krol Hill-Kamli Dhar* syncline. This is more complex, being built up of minor synclines and anticlines, often disposing the Krol lime-

stones in outliers. The following chief individual units are recognisable, in order from north-west to south-east :—

(*a*) Pachmunda and Krol synclines.
(*b*) Khanog and Rajgarh synclines.
(*c*) Narag-Dadahu stretch of continuous Krol limestones.
(*d*) Kamli Dhar and hill 3,619 feet synclines.
(*e*) The easterly continuation of the Kamli Dhar syncline with enclosed Tal rocks; the Korgai syncline.

This complex of synclines is bounded on the north-east by the Giri thrusts, and on the south-west by the Krol thrust.

The two main dislocations along the belt are the Krol and Giri thrusts. The Giri thrust has caused the most havoc, since the hard foundation of Jaunsar and Simla slates has been pushed upon incompetent Krol limestones. It has produced a series of minor thrusts and inversions in the Krol rocks, which are best seen on the northern face of Krol Hill. The thrusts are generally parallel to the limbs of the folds, *i.e.*, parallel to the bedding-planes of the beds making up these limbs.

The folds do not call for much comment. The Kamli Dhar syncline is markedly inverted through 120°, Krol B, Krol A and Infra-Krol all dipping to the north in inverted sequence. A singular feature of the Krol belt is the nature of the folding within the Krol D stage. The limestone bands twist and overfold amongst shales in an intricate manner, as may be seen in section No. III on Plate 25.

It should be pointed out that the irregular folding of the Krol and Infra-Krol rocks is due to their incompetent nature, and cannot be considered a feature of primary structural significance, peculiar to the particular zone of rocks that intervenes between the belt of Tertiary rocks to the south-west and the phyllite-schist zone to the north-east. The rocks concerned had not been stiffened up by any previous metamorphism at the time of the Tertiary orogenics, and the rapid alternations of limestone and shale would naturally permit intricacy of folding. The major features are thrust-sheets, just as is so in the schist zone to the north-east.

Krol Thrust.

The Krol thrust is the 'Main Boundary fault' of earlier writers who have described analogous areas.[1] From Solon to Dadahu it

[1] Middlemiss, *Mem. Geol. Surv. Ind.*, XXIV, pp. 19, 31, etc., (1890).

brings Infra-Krol and Blaini rocks against Subathu, Dagshai and Kasauli stages. Further east, Blaini, Jaunsar and Mandhali rocks override Subathus and eventually come to lie upon Nahans. It marks the approximate boundary between Krol and their foundation rocks (*Himalayan* of Medlicott) and the main belt of Tertiaries (*sub-Himalayan* of Medlicott).

Medlicott.

Medlicott did not map this boundary as a fault, since he believed that it represented the slightly disturbed cliff face that originally formed a boundary to the deposition of nummulitics, and against which the Nummulitics, Dagshais and Kasaulis were banked. In describing the area immediately to the south of Subathu[1], he stated that the junction between the Subathu and pre-Tertiary rocks, although giving the impression of a great fault line, was in reality undisturbed, the relative position of the beds in contact on the Boj (modern *Pachmunda*) being what they originally were. This view is certainly untenable, since, apart from any question of the Subathu-Infra-Krol boundary, the Subathus themselves occur faulted against Dagshais and Kasaulis. In considering the nature of the boundary, it must be remembered that Medlicott consistently believed that not only the one with which we are directly concerned, but also other boundaries, such as that between the Middle and Upper Siwaliks, in the Markunda *nala* south of Nahan, were tilted cliff faces. Thus on pages 107 and 108, he describes the superposition of Middle Siwaliks on Upper Siwaliks, stating that older observers regarded the sequence as natural. He was aware that similar puzzling sections had been found in the Alps, and of the usual assumption of 'prodigious faulting' to account for this abnormal superposition. Nevertheless, he finishes up by believing that the section was an original contact and that '*no fault at all has occurred*'. Similarly, on pages 115 and 116, he dismisses the northward dip of Nahans below pre-Tertiary rocks, near Mussoorie, as '*quam proxime*, an original one'. Medlicott is a difficult writer, whose arguments are not easy to follow, but it is clear that his whole position depended on this idea of slightly disturbed contacts of old vertical cliff walls against which the Tertiary rocks were successively banked. Below Mussoorie, these old cliffs must have been 10,000 feet high, because it is the upper part of the Nahans that is

[1] *Op. cit.* III, Pt. 2, pp. 83, 84, (1864).

juxtaposed against pre-Tertiaries, and, by hypothesis, the Subathus, Dagshais, Kasaulis, and Lower Nahans must all have been previously banked up against this wall, only to be covered up with the higher Nahans now actually seen. It cannot be supposed that the Nahans had overlapped beyond the Subathus in a north-easterly direction, and therefore be argued that the cliffs need not have been so high, because it is known that Subathus occur in this direction in places where the Nahans have never been found.

I have seen the sections both south of Nahan and below Mussoorie. To my mind, there is no alternative explanation to that of the existence of thrust planes. The thrust below Mussoorie is the continuation of the Krol thrust.

Dhaduwala section.

The sections in the Makunda *nala* south of Nahan, near Dhaduwala village, show gently dipping Upper Siwalik conglomerates, overlain by highly coloured Middle Siwalik 'Nurpur' sand-rock and clays. These clays are very soft. It is not likely that they would ever have formed a steep cliff. They do indeed form a cliff at the present day, but one that is marked out by terraces of earth pillars and highly crumbled sand-rock. Most certainly this sand-rock would have been incorporated in the Upper Siwalik sediments, had these been deposited, as was supposed, against it. No sign of the sand-rock is actually found. The pebbles in the Upper Siwaliks of this locality are solely those derived from the Lower Siwalik or Nahan sandstones. Neither do the Upper Siwalik rocks show the bright colours of the Nurpur beds.

The present junction between Middle Siwaliks and underlying Upper Siwaliks is a plane that dips northwards at angles of less than 45°. It is sometimes parallel, sometimes slightly inclined, to the bedding planes of the Upper Siwaliks. If this junction had once been vertical, but was later tilted over towards the south, as depicted by Medlicott in Figs. 14 and 15 of his memoir, it would be expected that, in proportion as the cliff face assumed parallelism with the beds that were originally deposited at right angles against it, so must there have been faulting. Medlicott himself speaks of 'boundless tangential forces' (page 110) and yet was unwilling to allow even limited reverse faulting to account for this contact, remarking that it was a relief to find an escape from the usual modes of accounting for such juxtapositions. It would be quite wrong to throw aside Medlicott's ingenious suggestion as being without value, but

it is clear that he exceeded its legitimate application in regard to the Krol thrust, and even to the thrust seen at Dhaduwala.

Medlicott also thought that Nummulitics did not occur to the north-east of the area where he had noticed them, a belief that was connected with his idea of cliff barriers. Later, Middlemiss found Nummulitics on the Tal rocks of Garhwal, and recently I have seen them on Krol limestones (page 403), and at Dabra, north of the Tons thrust. In all these cases they are often seen at higher altitudes than the Nahans found south-west of the boundary fault, and imply an elevation equivalent to their position in the geological succession below the Nahans, plus the height difference now seen. Some of this elevation of Nummulitics is, of course, due to folding, but the folds have only a fraction of the amplitude that would be required to bring the Nummulitics to the height above the Nahans at which they now occur. The sliding of a whole zone of rocks over a thrust-plane would readily account for this position.

Recent survey.

The recent survey of the Krol Belt has established conclusively the thrust condition of the contact between the pre-Tertiary and Tertiary rocks, though doubt is still left as to the importance of the thrust in the neighbourhood of Solon. Thrusts in that area are certain, but whether the Krol limestones of Pachmunda Hill form an outlier resting on an extensively thrust and folded *nappe* is not definitely proved.

The most convincing places for demonstrating the low angle of contact of pre-Tertiary rocks, with underlying Tertiaries, are the following:—

(*a*) In the Amlawa and Tons rivers, near Kalsi, where Mandhalis rest gently upon hardened red shales that are either Dagshai, Nahan or Middle Siwalik.[1] The dip of the thrust varies from 25° to 35°, northwards.

(*b*) Mapping shows the low angle of contact between the Infra-Krols and the Subathus between hill 4,217 feet and Dadahu.

(c) Between height 3,241 feet on the Kawal Khai river and hill 4,633 feet Infra-Krol and Blaini upon Subathus.

(*d*) Between the Blaini river and Bharech col, Infra-Krol and Blaini upon Subathus.

[1] Pilgrim, *Mem. Geol. Surv. Ind.*, LIII, p. 50 (1928), regarded these shales as Dagshai. They were taken by Oldham to be Nahan. They appear to me to be either Nahan or Middle Siwalik, being unlike the Dagshais of the type area. It is true that the shales are crushed and hardened, under the Krol thrust, so that resemblances may have been rather obscured, but I cannot see that Dr. Pilgrim could have had 'no hesitation' in regarding them as Dagshai. The question is immaterial to the matter discussed above. In the map I have coloured them as Nahan.

The thrust is not everywhere of the same gentle hade. North-west of Barog railway station it is even inverted for a short distance, between the motor road and the 5,800 feet contour, hading south-west. For most of the way between Narag and Dadahu, it has a very steep hade to the north-east.

The interpretation of the structure round Solon is one of great difficulty. It will be seen from the map that there is a narrow outcrop of Subathu rocks running up the Blaini river towards Solon, which is flanked by Infra-Krol rocks, and which itself has a core of Simla slates. The relations are shown diagrammatically in Fig. 1 on page 436. The Tertiaries are found to dip, both at steep and at gentle angles, beneath the Blaini, Infra-Krol and Krol limestones. They are known to rest at Subathu upon Simla slates. Across the Blaini valley there is the apparent succession.

Blaini, Infra-Krol and Krol limestones.

..........*(Krol thrust, inferred)*.

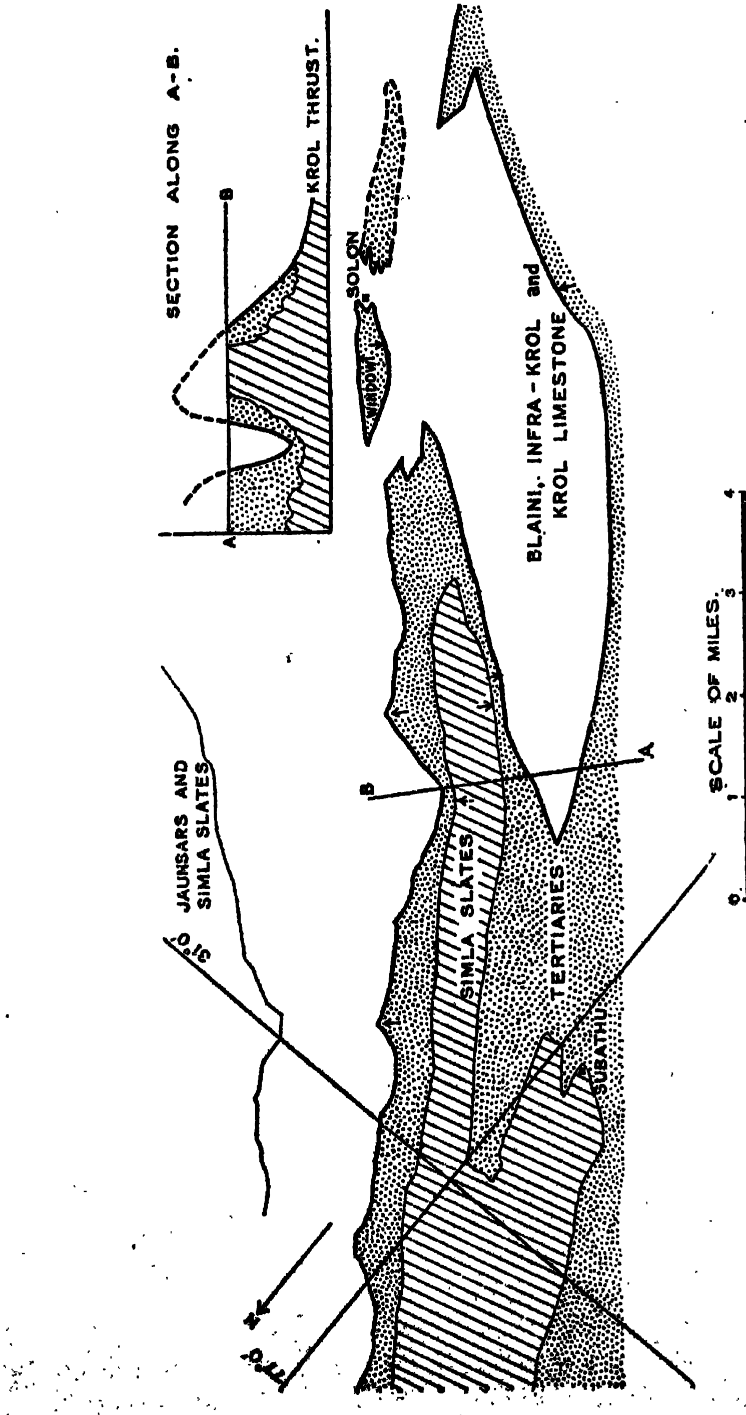
Subathus.

..........*(normal superposition)*.

Simla slates.

It is difficult to suppose that the Subathu rocks had been caught in two parallel and strongly pinched synclines amongst older rocks, because, if this were so, the enclosing older rocks of both limbs of the synclines should be the same. In reality, Simla slates are found in the middle of the Subathus, while Blaini–Infra-Krol flank them on either side. The apparent structure is that of a single anticline pitching to the south-east, with the sequence given above. Only by a curious accident could the Subathus have been deposited in a bay, bounded by cliffs of Blaini-Infra-Krol (now represented by Krol and Pachmunda Hills), and with a floor of Simla slates. Under these circumstances it would be possible to imagine that subsequent movement might fold the cliffs of Blaini–Infra-Krol over Subathus, and at the same time, elevate the floor of Simla slates. This is the view that Medlicott adopted. It implies that overfolding of the cliffs was negligible near Solon, but great to the north-west. It implies also that the cliffs at Pachmunda were folded on the south-west side over to the south-west, and on the north-east side over to the north-east.

There is no doubt about the normal unconformable superposition of Subathus on Simla slates. If the Blaini–Infra-Krol, with outliers of Krol limestone, are found to occur above Subathus, the



Arrows show general dip of contact. ——Trace of inferred thrust-plane.

FIG. 1.—Diagram showing structural relationships north-west of Solon.

alternative inference may be made that their position is due to thrust faulting, subsequent folding of which has led to the formation of the Pachmunda outlier and has exposed the underlying Subathus in a pitching anticline along the Blaini river and in two *windows* near Solon. The magnitude of translation, on this inference, is great, too great probably for those who look only at the Subathu/Infra-Krol contact near Barog station.

It can hardly be doubted that the Subathu/Blaini/Infra-Krol contact, north-east of the narrow outcrop of Simla slates, is a thrust. The curved nature of the outcrop of the dividing plane, with the V pointing north-east, into the valleys, shows that the plane is gently inclined. Further, the width of the Subathus between the Blaini–Infra-Krol and the Simla slates is very variable, expanding with depth. Neither can it be doubted that the contact seen south-east of Solon, between hill 4,633 feet and height 3,241 feet in the Kawal Khal, is also the trace of a thrust-plane.

It may be held, however, that these two thrusts join up near Solon, and do not swing round Pachmunda Hill, as is here supposed. Support for the objection could be found in the occurrence of the Subathu pisolite near hill 4,819 feet, immediately below the Blaini–Infra-Krol, from which it could be argued that the magnitude of translation could not be great if the original bottom bed of the Subathus is still preserved. This bottom bed also occurs in the Kawal Khal, where there is every reason to believe the thrust to be important. Its occurrence near the 4,819 feet thrust-contact could be regarded as fortuitous.

The issue is, in some respects, similar to the controversy concerning the Glarner fold in the Alps, which was at first interpreted as a double 'mushroom' fold, but was later considered to be a *nappe*-fold, based on a thrust-plane. I see no evidence apart from boring which will settle the question, but the explanation offered of a folded thrust-plane of great extent seems reasonable, bearing in mind the magnitude of the extensive thrusts known to exist along the Himalayan foothills.

Some indication that the Krol thrust is more than a minor feature is given by the fact that it overlaps the Nahan thrust (which separates Subathus from underlying Nahans) in an easterly direction. At

Nahan, the Nahan thrust is five miles distant from the Krol thrust. At Sataun it disappears, together with the Subathu rocks, and pre-Tertiaries rest directly on Nahans.

One of the most noticeable features of the Krol Belt is the change in strike near Dadahu from N. W.–S. E. to nearly east and west. Similarly, between the 31° and 32° latitudes, north of the area described in this report, the strike changes from N. W.–S. E. to nearly due north and south. A careful following of the boundaries between the stages in the Tertiaries might disclose the fact that the Krol thrust, and other thrusts separating the Tertiaries from the pre-Tertiaries, have caused an extensive tectonic overlap of older rocks upon younger, over a distance dependent on the amount of departure of the outcrop of the dividing plane from N. W.–S. E. My own observations amongst the Tertiary rocks were not extensive enough to prove the point.

The actual fold-axes in the Tertiaries appear to follow the same general change in strike that is shown by the Krol Belt, since the folds probably arose as a result of pressures initiated by the foreward movement of the belt over the Krol thrust. But a detailed examination of the fold-axes of the boundary planes between the folded stages, may well show that these are truncated by the Krol and analogous thrusts.

Giri Thrust.

The Giri thrust is a well-marked feature which has been traced from the Gambhar river to north-east of Chandni, where it dies out in an anticlinal fold.

It was noticed by Medlicott, who has shown a part of it very accurately.

North-west of Kandaghat, the thrust is steep and separates Simla slates from Jaunsars. Along the Ashmi river, its dip becomes gentler. Simla slates are thrust first over Infra-Krol, and then over themselves. The thrust has not been traced between Sunnu and Gauhra, but is seen in the Giri river below the Gauhra Rest House, where two facies of the Simla slates are separated with disturbance by an inclined fault. Further south-east, the thrust truncates an anticline of Blaini with underlying Chhaosa beds

belonging to the Simla slates, in the manner shown in the diagrammatic section below.

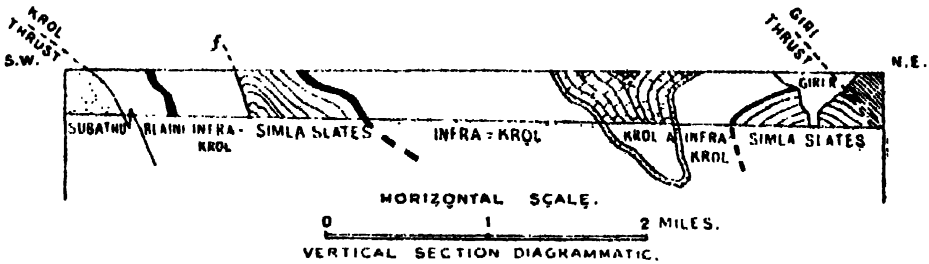


FIG. 2.—Diagrammatic section along Kawal Khal river (Blaini shown in black). Horizontal scale, 1 inch = 1 mile. Vertical section diagrammatic.

This is a modification of the sections given on pages 12 and 13 in *Mem. Geol. Surv. Ind.*, LIII, (1928). The Giri fault there marked is now regarded as a major feature, and its position has been changed from the south-west to the north-east limb of the anticline of Simla slates that runs along the Giri river. If the Blaini of Dudham should prove to be Mandhali, and if the Mandhalis occur normally between the Jaunsar and Simla series, there would be no need to postulate the Jaunsar thrust. The section above the Giri thrust would be a normal one.

Mapping is very difficult from height 2,820 feet down to Niwar, though the existence of thrusts is definite. Below Bongli, Jaunsars dip at 60° to the north-east upon Krol C. Two miles to the south-east the thrust is inverted, dips being to the south-west. At Milan, imbricated Jaunsars and Blaini again dip to the north-east at 40°-50° upon Krol C limestone. Eastwards the dip of the thrust varies. North-west of Kando, uninverted Jaunsars rest at a low angle on inverted Blaini. In the Nait ka khala, the Blaini is cut out, and Jaunsars overlie an inverted succession of Infra-Krol and Krol limestones. The Giri thrust then splits up into several minor, parallel, thrusts, which eventually die out in the Barbas anticline.

Tons Thrust.

The Tons thrust is a fairly well-marked feature which separates Mandhalis and Jaunsars from the underlying Morar-Chakrata beds. By height 2,206 feet, on the Tons river. Jaunsar rocks occur in the 6,000-foot scarp on the right bank, dipping south-west, while on the

left bank occurs the Deoban limestone, dipping apparently to the north-east in cliffs and terraces nearly 7,000 feet in height. A great dislocation is therefore required to explain the juxtaposition of unlike rocks on the two sides of the Tons river.

In connection with the present discussion, the important point is that the Tons thrust dips to the south-west and south. Since the Krol thrust dips northwards, it is possible that the two thrusts are the same, and that the great syncline of Jaunsar rocks, with overlying Krols and Tals, rests as a *nappe* on a folded thrust-plane. Should this be so, the Krol thrust would be of premier importance in the structure of the area. No information is to hand to prove the point.

Below the Tons thrust occur Simla slates, together with soft purple sandstones of Dagshai [1] type and Nummulitic beds. Definite Nummulitic limestones, associated with vitreous quartzites and green shales, are seen at Dabra. It is very probable that the lenticular limestones, shattered white quartzites and green shales that crop out between the 3,500- and 3,250-foot contours on the path from Sarog to Sayasu, are also Nummulitics.

To what extent the purple sandstones are Tertiary is impossible to determine. At Kailana and along the Seli Gad to the east, mottled purple sandstones occur interbedded with the concretionary facies so typical of the Chhaosa type of the Simla slates and may reasonably be considered to belong to the Simla slates. Moreover, Dagshai-like sandstones occur as boulders in the Blaini, boulder bed, which is without question pre-Tertiary, and is with fair certainty pre-Mesozoic, thereby proving that there must be at least two series of sandstones of similar type, one pre-Mesozoic, the other Tertiary. It does not follow that all these sandstones north of the Tons thrust must belong to the Simla slates, but only that they cannot all be Dagshai.

This occurrence of Nummulitics below both the Krol and the Tons thrusts is suggestive of the possibility that they are continuous beneath these thrusts. The centripetal disposition of Nummulitics below the Inner Schistose series of Garhwal may be recalled.[2] It is true that Middlemiss did not favour the idea, which he himself brought forward, that the Inner Schistose series occurred as a *Klippe* upon continuously underlying Nummulitics, but a

[1] *See Mem. Geol. Surv. Ind.*, LIII, p. 38, (1928).
[2] *Rec. Geol. Surv. Ind.*, XX, pp. 34, 36, (1887).

re-examination of the Garhwal area may eventually establish that this is so.[1]

The question of the identity of the Krol and Tons thrusts has yet to be settled, but it seems reasonable, in view of the similar tectonic sequences on either side of the Jaunsar syncline, to regard them as one and the same thrust that has been subsequently folded.

Small-scale Structures.

It is unnecessary to describe in detail the varied reactions of different rock facies to stress. The following five sketches, all drawn from photographs, will give a fair indication of the complexity that prevails. Reference should also be made to Plate 21, fig. 1, and to Plate 22.

The Subathus, the Krol B and D stages and the Infra-Krol have suffered the most disturbance. The complexity of folding

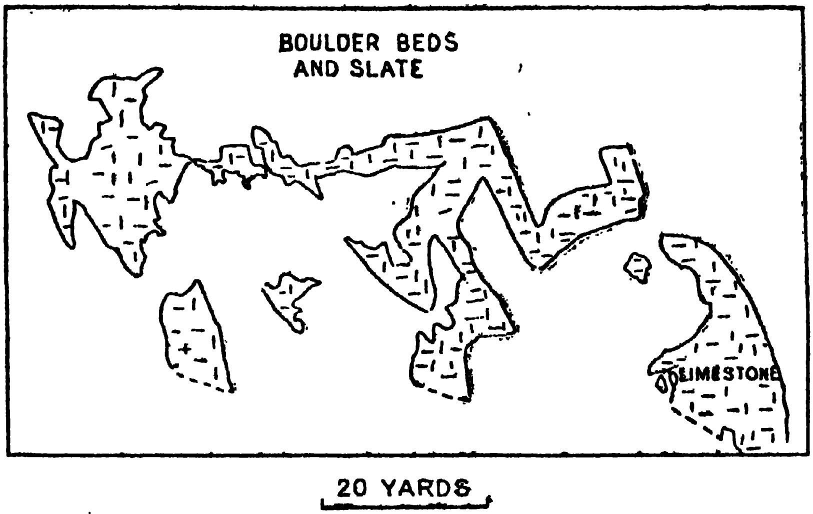


FIG. 3.—Interdigitation of Blaini limestone in boulder beds and slates, left bank of the Jagar ka Khala, near confluence with Giri river.

[1] Middlemiss was aware in 1887 of the thrust structures that were at that time being discovered in the North-West Highlands of Scotland, but he considered that the Garhwal area, examined on its own merits, did not warrant similar deductions. It is possible that the great *nappe* structures found in the Alps predispose geologists to find them elsewhere in analogous orogenic belts. Even allowing, however, for such a predisposition, and for an unconscious neglect of facts that might negative explanation of structure by *nappe* formation, the undeniable existence of such structures in many mountain-chains makes it probable that another interpretation may be put on the structures present in Garhwal.

and fracture shown by such soft rocks when caught up in orogenic movements, is greater than that of the older, more indurated rocks. Rocks previously converted into quartzites, slates and clay-slates will already have attained a certain degree of stability and competence before the oncome of the Tertiary orogenics. These competent beds would act as structures capable of resolving the Tertiary stresses into definite directions. This is not so with the Subathus, in the soft sandstones and shales of which adjustment to strain has been irregular and without orientation (see Figs. 4 and 5).

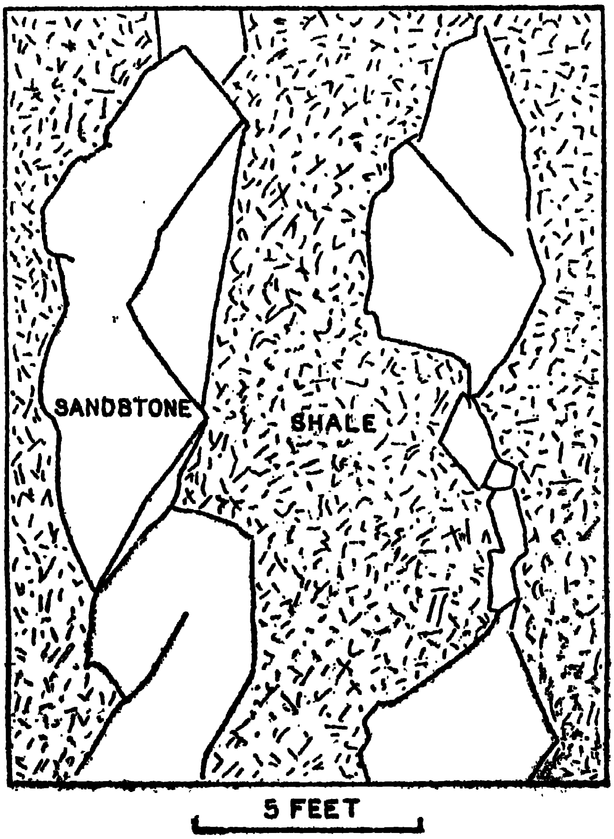


FIG. 4.—Attenuated beds of sandstone in shale, Subathu stage, Gambhar river, one mile east of Haripur.

Induration is not the sole factor. The shales and sandstones of the Dagshais are no more indurated than those of the Subathus, but yet the Dagshais are folded in a much simpler and more regular

manner. Further, the shales and limestones of the Krol D stage in the east of the area are less contorted than those of the same stage near Mangarh. This may be explained by the fact that the

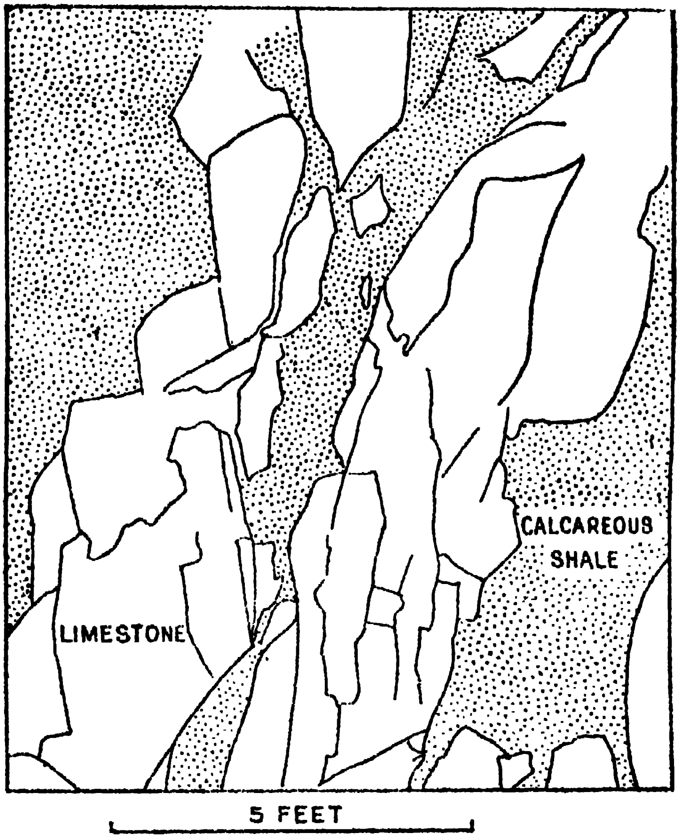


FIG. 5.—Shattered beds of limestone in calcareous shale, Subathu stage, left bank of Koshallia *nadi*, two miles E. S. E. of Kalka railway station.

very regular alternations of *equal* thickness of sandstone and shale in the Dagshais, and of limestone and shale in the eastern development of the Krol D stage, tend to prevent unequal redistribution of material. Other factors, such as the protective influence of the Tal beds on the underlying Krol rocks, are also of importance.

The complexity of miniature folds and thrusts in the Mandhali limestones (Fig. 6 on page 444) is due to the original lenticular habit of the limestone and phyllite, by which the many discontinuous beds of limestone would each tend to fold individually within the more

general phyllitic matrix. It may be presumed that the greater angularity of folding and fracture of the Mandhali limestones in

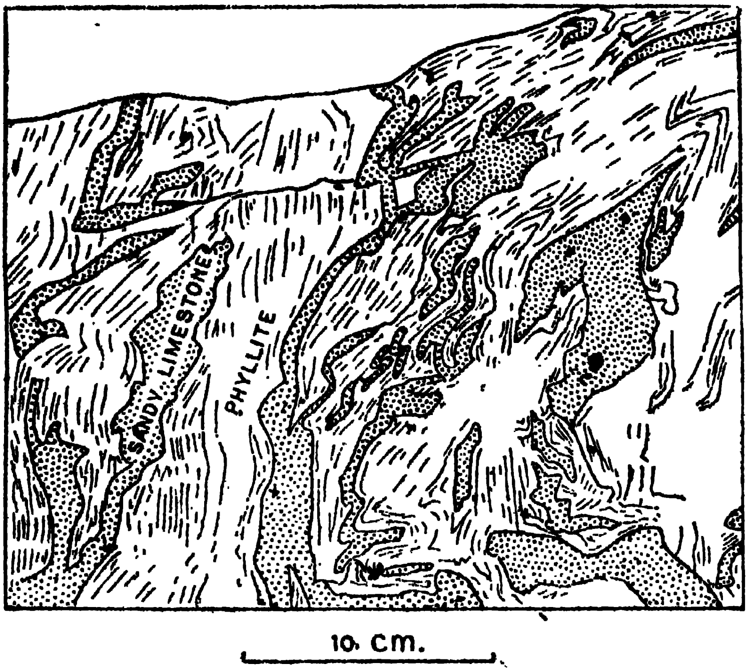


FIG. 6.—Twisted lenticles of sandy limestone in phyllite, Mandhali beds, 0·6 miles north of Sataun, Giri river.

comparison with those of the Krol A stage (Fig. 7) is due to the fact that the argillaceous phase in the Mandhalis was already a clay-slate or phyllite at the time of the folding, and therefore reacted in a more rigid manner.

Age of Thrusting.

In the Kalsi area, the Krol thrust brings pre-Tertiary rocks to rest upon Nahans. The thrust must therefore be of Miocene or later age.

At Bilaspur, Krol limestones are seen to rest at 30°–40° upon Upper Siwalik conglomerates. The latest movement of the thrust here cannot be older than Pliocene.[1] The same inference applies

[1] This thrust has not been joined up with the Krol thrust of the area included in the map.

to the thrust at Dhaduwala, south of Nahan, which brings Middle Siwaliks to rest upon Upper Siwaliks.

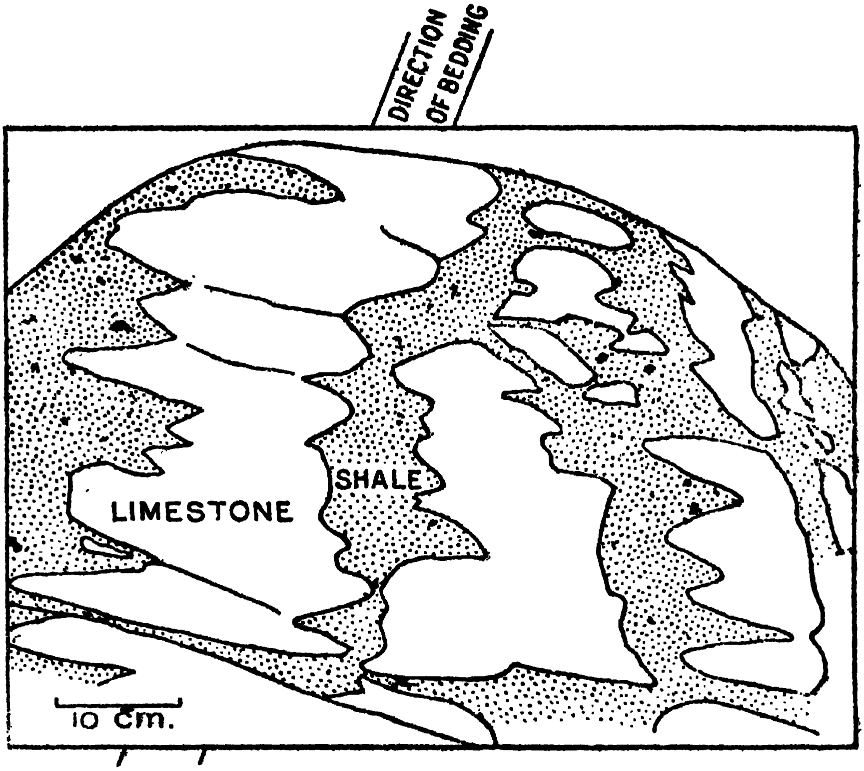


FIG. 7.—Yield of impure limestone, by flow, in calcareous shale, Krol A stage, a quarter of a mile W. S. W. of height 3,278 feet, Nera (Newali) *nala*. Compare with Plate 22 in which deformation is less.

In contrast to this dating, Middlemiss[1] found that the Upper Siwalik conglomerates have overlapped the Nahans, on to the traps of the pre-Tertiary rocks, truncating the Main Boundary fault. This proves that the Main Boundary fault of Garhwal was pre-Pliocene. Middlemiss also notes that a later reversed fault, in the same Gangolia locality, has brought Middle Siwaliks on to Upper Siwaliks. The thrusting must, therefore, have continued over a considerable length of time.

Morphology.

A difficulty is raised by the late age of some of these thrusts. By Pliocene times, the main drainage system of the Himalaya is believed to have been well established. The late Pliocene thrusts must, therefore, have act-

[1] *Mem. Geol. Surv. Ind.*, XXIV, p. 107, (1890).

ed on a region already largely dissected into separate orographical areas. To what extent these areas, with intervening river valleys, limited the nature of the tectonic structures present in them, will be very difficult to decide. Once a river has carved down several thousands of feet, it may be presumed that pressures above the level of the river must have been confined to the orographical units in which they occurred, and must have been relieved by structures peculiar to those units. The Krol thrust certainly crosses the Tons and Jumna rivers undeflected, so that the whole of the Krol Belt must have moved forward as a tectonic unit before the rivers had cut down to their present levels and had divided up the country into the modern orographical areas.

Ampferer has described *relief-overthrusting* in the Alps, by which translation of rock masses has taken place over a topography previously determined by subaerial erosion.[1] The whole question of morphology in relation to tectonic history is, however, too difficult to discuss here.

Inclination of Thrusts.

The inclination of both the Krol and Giri thrusts is found to be very variable, in some places being only 20°, in others inverted. Mr. P. Lake[2] has deduced that the thrust-plane at the base of the Himalaya must have a dip, at its outcrop, of 14°. He suggested in 1903 that the visible boundary faults of the Himalaya are probably minor thrusts, since the actual base of a modern mountain chain would be obscured by the products of its own denudation (Siwaliks and modern Ganges alluvium). Dr. Fermor[3] has drawn attention to a paper by Mr. Middlemiss[4], in which the inclination of the thrust at Kotli between the Murrees (Dagshais) and the underlying Middle and Upper Siwaliks, is actually 12° to 15°. This thrust was taken by Dr. Fermor to be the Main Boundary fault, and Mr. Lake has accordingly allowed that the real basal thrust-plane of the Himalaya does in fact crop out, and at an inclination

[1] *Jahrb. geol. Bundesanst. Wien*, LXXVIII, p. 241, (1928).
[2] *Geol. Mag.*, p. 305, (1903); *op. cit.*, p. 34, (1931). *Geog. Journ.*, LXXVIII, No. 2, p. 151, (1931).
[3] *Rec. Geol. Surv. Ind.*, LXII, p. 410, (1929)
[4] *Op. cit.*, L, p. 122, (1919).

that agrees with the theoretical value. Mr. Wadia[1] has shown that this thrust cannot be considered a boundary fault. It does not form a limit to the deposition of the Siwalik sediments, and, moreover, it terminates a short distance to the northwest in an anticlinal fold. The point at issue, however, is not the actual nature of the thrust-plane described by Middlemiss, but the variability of inclination of most of the Himalayan thrusts. Mr. Wadia agrees with me in the experience that a thrust may change greatly in dip within a distance of a few miles. The thrusts began, doubtless, with a rapid forward movement, when elastic limit was reached, but they must have slowed down as this original stress was relieved, and as resistance of the underlying and frontal foreland became greater. Cadell's experiments[2] have shown that horizontal pressure applied at one point is not propagated far forward into the mass, and it seems legitimate to suppose that, in proportion as pressures in one part are relieved, so would new pressures and strains arise in the part to which the thrust masses have been translated. It would be expected that increase in frontal resistance would tend to cause the folding of the whole structure of overthrust mass, and overridden mass, as a single unit. The original disposition of the thrusts, that might have better accorded with theoretical inclinations required for movement along plane surfaces, would consequently be obscured.

Further, the rocks undergoing folding and thrusting are not homogeneous, and it would hardly be expected that relief from pressure would take place with mathematical perfection. The resistance offered by the Bohemian *massif* to the advancing Alpine folds may be cited as an example of the kind of deflection that is caused by the local presence of a stiff unit of the foreland.

The coincidence of the theoretical inclination of 14°, deduced by Mr. Lake, with the observed inclination of a part of the Kotli thrust must be fortuitous. It may, moreover, be questioned whether there is a single thrust, of unique importance, to which Mr. Lake's deductions can be applied. It appears to the writer that the conception of a 'Main Boundary fault', and hence of a basal thrust-plane to the Himalaya, has been carried too far. It arose at a time when the faults were thought actually to mark the successive limits of sedimentation against the uprising Himalaya,

[1] *Mem. Geol. Surv. Ind.*, LI, Pt. 2, (1928); map at the end of Memoir.
[2] *Trans. Roy. Soc. Edin.*, p. 337, (1890).

and when the structure of the pre-Tertiary rocks had not been examined in detail. Recent work by Pilgrim, Wadia, West and the writer has shown the number of thrusts that actually exist in these pre-Tertiary rocks. Some of these cannot be considered minor structures, comparable solely with the minor thrusts, as distinct from the major thrusts, of the North-West Highlands. The Chail thrust of Mr. West is of premier importance. In the Himalaya, as in the Alps, it would appear impossible to regard any single dislocation or *nappe* as having borne the whole burden of the advance upon the foreland.

Pre-Tertiary Structures.

A brief note has already been published[1] in which the existence of structures showing a N. E.-S. W., Aravalli, orientation was discussed.

The observations were scattered over a wider area than that here described. Actually along the Krol Belt, the following structures may be noticed :—

(1) In the Palor Ka Khala, above Siyun; conglomerates in the Jaunsar series have been crushed, so that the pebbles have been elongated to ellipsoids, the major axes of which strike 60°–240°. The elongation is seen on dip surfaces. Along one direction at right-angles to the dip surface, the pebbles appear more or less circular. Dip of conglomerates: 30° to E. N. E.

(2) The Jaunsar phyllites at Shallai are thrown into small-scale folds, the size of mega-ripples, the axes of which vary in strike from 80°–260° to 60°–240°. In addition, there are grooves and striæ, on the bedding planes of these phyllites, which strike 35°–215°. These resemble glacial striæ, but are found on close inspection to be minute cross-folds running in the direction of dip of the false cleavage. They appear to resemble the grooves described by Dr. Fermor [2], except that they have no connection with the pitch of the synclinal fold in which they occur. Dip of phyllites and quartzites: 30° to S. S. W.

(3) The Blaini boulder bed on the ridge between Juin and Chandpur summits, has been made schistose. The direction of elongation of the pebbles varies from N. E.-S. W. to E. N. E.-W. S. W. Dip of boulder beds: due west.

(4) The schistosity of the Jaunsar quartz-schists, in the Shamanah ka Khala, below Andra, strikes 45°–225°, the shear-cleavage dip being 70° towards 315°. Dip of quartzites: 65° to S. S. W.

[1] *Rec. Geol. Surv. Ind.*, LXVI, p. 467, (1933).
[2] *Econ. Geol.*, XIX, p. 560, (1924).

These directions are at right angles to the strike now shown by the Himalayan range. They suggest that pressures had formerly acted in approximately a N. W.-S. E. direction, which is the same direction as that of the pressures responsible for the formation of the Aravalli range and its subsequent rejuvenation.

If the Aravalli range be produced across the Gangetic alluvium, it meets the present Himalaya in the region between Chakrata and Naini Tal. It seems a legitimate assumption to regard those structures of N. S.-S. W. orientation in the present Himalaya as having been caused by activity along the Aravalli axis. Such structures have never been noticed in the Infra-Krol and higher series, so it may be assumed that the activity responsible for them ceased in Blaini times, that is, during the Upper Carboniferous.

It has already been stated on page 400 that the folding which was responsible for the unconformity of Blaini upon Jaunsar rocks probably did not have an Aravalli direction. There is therefore a certain degree of anomaly, since the Blaini of the Juin-Chandpur ridge appears to show this Aravalli orientation. Further, no unconformity of orogenic violence is seen between the Blaini and the underlying Jaunsar and Simla series.

The two sets of facts must be left together and unexplained. The commonness of N. E.-S. W. structures in the Himalaya cannot be disregarded. Moreover, they cannot be explained by supposing that their formation was due to strongly rotational Tertiary stresses, since the post-Blaini rocks all show a true Himalayan, N. W.-S. E., orientation of structure.

Besides the structures that I have myself recorded from Garhwal, Middlemiss [1] mentions the prevalence in the Kumaon of folding and cleavage of pre-Tertiary rocks in a north-south direction, which he attributes to an east-west pressure.

It may be maintained with safety that the modern Himalaya contain relics of structures that were due to earlier, non-Himalayan, tectonics.

XII. ECONOMIC.

The country is very poor in minerals.

It should be remarked that in no instance has any mineral been seen to occur in sufficient quantity to justify exploitation.

[1] *Mem. Geol. Surv. Ind.*, XXIV, p. 125, (1890).

Barytes.

Barytes occurs, or may have occurred, in the following localities. In all cases it is found in the older rocks.

(1) A discontinuous vein of barytes occurs in the Simla slates near hill 3901 (30° 58′ 30″ : 77° 1′ 15″), two miles E. S. E. of Subathu, on the border of Bharauli and Baghat State. It is about four feet thick and occurs along a fault-plane. It can be traced sporadically for about a mile to the south-east. The barytes contains galena, but in very small amount. The old workings are now almost overgrown with vegetation.

(2) Dr. A. L. Coulson has drawn my attention to references concerning old lead-mines in the same neighbourhood, and I have drawn verbatim from the information he has collected.

'Kelly [1] and Henwood [2] have described mines not far from this neighbourhood, but they have made no mention of barytes.[3] Ball[4], however, gives three localities where ores of lead are said to occur. It is thought that the first of these, namely, "2½ to 3 miles south-east of Huriapur" is the locality mentioned by Mr. Auden.[5] "Huriapur" is probably the village "Haripur" (31° 01′ : 76° 59′) on sheet 53 A/16. Ball adds :—

> "traces of lead ores with barytes are said to occur to the east of the suspension bridge, as far as the Sairan dak bungalow, on the Simla road, but (that) they do not occur to the west."

Sairan is probably Sair (53 E 4, 31° 05′ : 77° 03′), on the track from Subathu to Simla.'

(3) An old working is seen in a *nala* which joins the Kawal Khal at 30° 50′ 30″ : 77° 10′ 20″, Patiala State. It is in Simla slates. No trace of ore was seen and the villagers have no recollection of what was obtained.

(4) In the Jagar ka Khala, Sirmur State (30° 37′ 30″ : 77° 28′), small veins of barytes are found in the Blaini boulder bed. The barytes is much mixed up with shale and effervesces with acid. Specific gravity, 3·94. No galena was seen.

Gypsum.

Gypsum is found in the Krol limestones in the following localities :—

(1) Near Bhaunrari, Sirmur State (30° 47′ : 77° 14′). Small pockets of gypsum occur in Krol D limestone. These are probably replacement pockets.

[1] *Min. Journ.*, pp. 59-60, (1869).
[2] *Op. cit.*, pp. 67, 471.
[3] *Cf.* La Touche, Bibliography, Pt. 1B, p. 19.
[4] *Econ. Geol.*, p. 305, (1881).
[5] *Rec. Geol. Surv. Ind.*, LXII, p. 31, (1930).

(2) Ridana, Sirmur State (30° 33′ 22″: 77° 44′ 51″). A lenticular bed of gypsum, 20 yards long and a maximum of 18 inches in thickness occurs in Krol A limestone. The specific gravity of some of the material gave the value 2·705, so that there is probably an admixture of gypsum and anhydrite. The greater part of the mineral is gypsum, with specific gravity of 2·306. The deposit appears to be an original one, and not due to replacement.

Seepages.

In 1928, the Maharaja Sahib of Baghat State asked me to examine some reputed occurrences of iron, near Harat. The material is ferric hydroxide, and occurs as seepages from the Infra-Krol slates. Such seepages are found all along the outcrop of the Infra-Krols, but do not indicate anything of economic interest. White salty efflorescences often occur on the black Infra-Krol slates. Analysis shows them to contain the following radicles:—Cl, SO_3, K, Mg, Ca, and Fe.

XIII. LIST OF PLATES.

XIV. LOCALITY INDEX.

	Latitude.		Longitude.	
	°	′	°	′
Juin Hill, 8,493 feet	30	42	77	36
Kadhar	30	57	77	06
Kalka	30	50	76	57
Kalsi	30	32	77	51
Kamli Dhar	30	37	77	31
Kandaghat	30	58	77	06
Kando	30	38	77	27
Kandon	30	33	77	30
Kasauli	30	54	76	58
Katiara	30	58	77	03
Khadayat	30	39	77	41
Khanog Hill, 6,517 feet	30	53	77	07
Khur	30	39	77	30
Korgai	30	33	77	41
Kotla	30	39	77	23
Krol Hill, 7,393 feet	30	57	77	06
Koti Dhaman	30	38	77	33
Kyari	30	43	77	41
Lakhwar	30	32	77	58
Lagasan	30	54	77	09
Lansdowne	29	50	78	41
Mangal	30	41	77	38
Mangarh	30	45	77	15
Manogi	30	35	78	02
Mareog	30	53	77	13
Masria	30	51	77	11
Milan	30	41	77	23
Milla	30	40	77	38
Minal Bag	30	37	77	43
Mishwa	30	37	77	38
Morar	30	40	77	46
Naga Tibba	30	36	77	50
Nagthat	30	34	77	58
Narag	30	49	77	11
Narail	30	43	77	20
Naraya	30	40	77	50
Niwar	30	48	77	17
Pathna	30	33	77	47
Rajana	30	40	77	27
Rajgarh Hill, 6,941 feet	30	53	77	10
Rerli	30	41	77	25
Sainbar Hill, 6,714 feet	30	46	77	15
Sahiya	30	37	77	53
Salogra	30	56	77	08
Sataun	30	33	77	38

	Latitude. °	′	Longitude. °	′
Senj	30	59	77	08
Shali peak	31	12	77	17
Shallai	30	40	77	42
Shalamun	30	52	77	14
Shiwa Kalan	30	34	77	45
Siyun	30	42	77	22
Soat Hill	30	41	77	26
Solon	30	55	77	07
Subathu	30	58	76	59
Sunny (Sunnu)	30	56	77	10
Tikar	30	42	77	30
Tikari	30	39	77	25
Udpalta				

Heights.

1,808 feet	30	32	77	54
2,206 feet	30	44	77	43
2,820 feet	30	50	77	15
3,241 feet	30	50	77	10
3,278 feet	30	39	77	38
3,619 feet	30	36	77	28
4,217 feet	30	34	77	29
4,633 feet	30	51	77	08
4,819 feet	30	57	77	02
4,960 feet	30	58	77	03
6,458 feet	30	34	77	43
6,474 feet	31	00	77	06
6,925 feet	30	40	77	54
7,005 feet	30	40	77	29
7,216 feet	30	40	77	30

ON SOME CRUSH CONGLOMERATES OF DHARWAR AGE FROM CHOTA NAGPUR AND JUBBULPORE.[1] BY M. S. KRISHNAN, M.A. (MADRAS), PH.D. (LONDON), A.R.C.S., D.I.C., *Assistant Superintendent, Geological Survey of India.* (With Plates 26-29.)

INTRODUCTION.

In this paper are described some crush conglomerates occurring in the Gangpur State of Bihar and Orissa and in the Jubbulpore district of the Central Provinces. In both cases they form part of the Dharwar sequence. Conglomerates from other parts of India and from similar formations have been described, except in a few cases, as of autoclastic origin. It is the aim of the writer to show that those dealt with here are of sedimentary origin, though locally, the crushing and shearing have been so intense as to obliterate the original nature and impose autoclastic characters.

OCCURRENCE AND GEOLOGICAL RELATIONSHIP.

In Gangpur State a very conspicuous zone of conglomerate occurs at the top of a sequence of Dharwar rocks consisting of mica-schists, phyllites, manganiferous rocks of the gondite type, dolomitic and calcitic marbles, and carbonaceous phyllites and quartzites. This zone forms the southern border of the Gangpur anticlinorium and stretches almost continuously from near Jaraikela (22° 18′ : 85° 7′) to Bamra (22° 3′ : 84° 17′), one to three miles north of the Bengal-Nagpur Railway track connecting the above two stations. Some outlying outcrops belonging to the same zone occur near Kolpotka (22° 22′ : 85° 6′) on the east, and at Bijadih (22° 4′ : 84° 15′) and Amasranga (22° 1′ : 84° 11′) on the west. This has a general E.-W. strike which varies at either end to E. N. E.-W. S. W., and a dip of 75° to 90° towards the south.

[1] Paper read before the Geology Section of the Twentieth Session of the Indian Science Congress, Patna, (1933).

In this region other conglomerate zones occur in association with masses of quartzite forming the Gamburu-Durgapata ridge in the south-eastern corner of sheet of 73 B/S. E., and in the Bhaisamunda *pahar* (22° 2′ : 84° 46′), a few miles to the west of the former. These are believed to be members of the Iron-ore series. The dip is fairly steep towards the north and the strike the same as that of the first zone, *i.e.*, nearly E.–W.

In the Jubbulpore district of the Central Provinces, conglomerates occur in the area to the east and E. S. E. of Sleemanabad (23° 38′ : 80° 15′). The main formations here are dolomitic marbles and mica-schists in which a few bands of conglomerate are found. These bands vary in thickness from a few feet to about a hundred feet. The two thickest ones are situated one mile south of Bhitrigarh (23° 37′ : 80° 25′) and a quarter of a mile north of Ghunsa (23° 35′ : 80° 21′), respectively. Other thinner beds are found near Mehgawan (23° 39′ : 80° 22′), Durghati Piparia (23° 38′ : 80° 24′), Bhadanpur (23° 34′ : 80° 22′) and Sahdar (23° 34′ : 80° 23′).

The formations in the Jubbulpore area were originally considered as belonging to the Bijawars[1] by C. A. Hacket, but subsequent examination by Dr. L. L. Fermor led to their inclusion in the Dharwars.[2] In addition to their approximate identity in age, there is a great deal of similarity in the lithology of the rocks in Jubbulpore and Gangpur. But, as is common with rocks of Pre-Cambrian age occurring in widely separated areas, a direct correlation connot be made with any degree of certainty.

Description of the Conglomerates.

The general mass of rock in the main band in the Gangpur area is a medium-grained, micaceous quartz-schist with quartz and subordinate muscovite as the chief constituents. When followed along the strike, the conglomerate bed shows some variation in thickness and sometimes grades into gritty schists. The typical rock shows a number of flattened pebbles in a mass consisting of fine-grained, highly quartzose, micaceous schist. The boundaries of the pebbles are generally clean and marked by films of muscovite. The pebbles are flat ellipsoidal in shape, the flat faces lying on the shear-plane and sometimes showing slickensides.

[1] Hacket's manuscript reports for the seasons 1869-70 and 1870-71.

[2] *Mem. Geol. Surv. Ind.*, XXXVII, p. 805, (1909).

Type A.

Specimens belonging to this type are best termed gritty quartz-schists containing no pebbles of comparatively large size. They form a transition between quartz-schists on the one hand and conglomerates on the other. They show a schistose structure (Plate 28, fig. 1) and medium to coarse texture. A small quantity of muscovite is interspersed among the grains, and sometimes films of this mineral show slickensides as evidence of shear (*e.g.*, specimens 38·59, 38·147, 38·156,[1] etc.).

Under the microscope the quartz grains are seen to be of various sizes, with a distinct tendency to parallelism of arrangement. Some are quite rounded, while others are sub-angular or angular. The larger grains are surrounded by finer ones and all generally show undulatory extinction.

Type B 1.

Under this type are included conglomerates and crush breccias of the Gangpur region. All of them are predominantly quartz-conglomerates, the pebbles being made up of quartzite, micaceous quartz-schist, translucent vitreous quartz and fine-grained biotite-schist in the order of diminishing abundance. Occasionally, tourmaline-quartz-rock is also found as pebbles (40·86).

The type illustrated by specimen 43·207, which was collected from the foot of the hill on the Singhbhum-Gangpur boundary near Baliam (22° 8′ : 85° 1′), is properly called a crush breccia. It is variegated in appearance, the groundmass being dark greenish grey and the pebbles white to grey. The groundmass contains chlorite, sericitic matter, some biotite and magnetite (Plate 28, fig. 2). The pebbles are of translucent quartz, white to pinkish quartzite and banded blue-grey quartzite. Specimen 37·949, from the hill one mile north of Bisra (22° 15′ : 85° 0′), resembles the above but is somewhat more sheared. The groundmass contains a little tourmaline in addition to the minerals seen in the other specimen. Another specimen (44·170) collected from near Kusumdih (22° 1′ : 84° 46′) is rather less crushed than the two mentioned above.

Type B 2.

Under this may be included all the other occurrences of conglomerate in the Gangpur region, as practically all of them show

[1] Numbers such as 38·59 refer to the registered specimens in the rock collections of the Geological Survey of India.

the effect of intense shear. Specimens broken across the schistosity reveal long, lenticular, inter-digitating pebbles, cemented by quartzose and micaceous material. The pebbles are of saccharoidal quartzite, muscovitic quartz-schist, biotite-quartz-schist and occasionally even phyllite (37·948; Plate 28, fig. 3). Occasional pebbles of granite (Plate 28, fig. 4) were noted in the exposures near Kolpotka (37·888 and 37·889), and of tourmaline-quartz-rock in the Mahabir *pahar* (22° 8′ : 84° 21′). In a few cases, there is little or no difference between the nature of some of the pebbles and that of the groundmass [40·94 from near Salebira (22° 6′ : 84° 13′), and 40·150 from the ridge just to the north of Bhaisamunda *pahar*], so that these pebbles are undoubtedly of autoclastic origin.

In the Jubbulpore area, the occurrences can conveniently be classified into three types of conglomerate and one of breccia.

Type C 1.

The ridges near Bhitrigarh, Ghunsa and Durghati Piparia all consist of conglomerates containing large pebbles of quartzite, which sometimes attain to a length of about twelve inches. The average size is, however, between three and six inches. Specimen 44·41 (Plate 26, fig. 1) is a good example of this, collected from a quarry near Durghati Piparia. The pebbles in this are well rounded, apparently by the action of water. Their surfaces are generally smooth and clean. The groundmass is composed of fine-grained quartz with a little sericite and ferruginous matter and occasional small cubes of pyrite. Compared with the others, this type seems to have undergone the least amount of crushing.

Type C 2.

This is found in some of the smaller ridges, and particularly the one near Mehgawan (specimens 44·42, 44·48, 44·49). The effect of crushing is evident in the broken-up sub-angular pebbles (Plate 26, fig. 2), some of which have been recemented after a little differential movement. Secondary veinlets of quartz can be seen to run through the groundmass and pebbles uninterruptedly. Under the microscope (thin sections 21933, 21937[1]), the larger grains

[1] Numbers such as 21933, etc., refer to the registered number of the thin section in the collections of the Geological Survey of India.

of quartz are seen surrounded by finely granulated material (Plate 29, fig. 1), which consists of quartz, chlorite, sericite and ferruginous matter. The pebbles are of quartzite and chalcedonic quartz or chert. It is interesting to note that the latter, on weathering, become opaque and granular and indistinguishable from quartzite.

Type C 3.

The band occurring near Sahdar, which is about twenty feet thick, shows sub-angular pebbles of quartz and banded hæmatite-quartzite (Plate 27, fig. 1, specimen 44·44). The rock is grey in colour. Under the microscope (thin section 21935, Plate 29, fig. 2) the banded structure of the pebbles is well seen. The iron-ore is bright steel-grey in reflected light, granular in texture with a fairly marked tendency to develop crystal outlines. It is not magnetite since it is not attracted by a magnet. The quartz of these pebbles is fine-grained and granular and varies somewhat in size in different bands.

Type D.

This type, represented by specimen 44·39 (Plate 27, fig. 2), is a breccia forming the main mass of the ridge situated about a third of a mile north of the original site of Amehta village (23° 39′ : 80° 23′). A rest house of the Irrigation Department has recently been built on this ridge. The rock is composed of white quartz, which cements the broken fragments and wisps of a dark blue-grey quartz of an earlier age. The colour of the latter is seen under the microscope to be due to dusty black inclusions (section 21930).

The dark quartz seems to have been first brecciated, and into this the white quartz injected at a later date. The latter, which is of the nature of vein-quartz, has been injected more than once, as earlier veins are often seen to be intersected by later ones.

OTHER ANCIENT CONGLOMERATES IN INDIA.

A large number of occurrences of conglomerates has been recorded from rocks of similar age in different parts of India, a fairly

large proportion of which being from Mysore. The majority, including the all the Mysore occurrences, have been assigned to the autoclastic group.

Bruce Foote[1] has described several conglomerates and boulder beds in the Lower Transitions of the Bellary district, Madras. They have all been regarded by him, presumably, as sedimentary. Dr. L. L. Fermor[2] has observed a conglomeratic grit underlying the manganese-ore band at Ukua and Balaghat in the Central Provinces. It is regarded as a metamorphosed conglomeratic grit, containing pebbles of white quartz, granite and gneiss set in a matrix which resembles mica-gneiss in general composition. Mr. J. M. Maclaren[3], working in the Tungabhadra region in Southern India, came across some boulder beds and conglomerates in which the pebbles and boulders of granite, aplite, quartz-porphyry, quartzite and banded jasperoid quartz are found embedded in a schistose felspathic matrix with some chloritic matter. These have been classified by him under sedimentary rocks. Some conglomerates of the Aravalli system, described by Dr. A. M. Heron[4], and considered by him as of sedimentary origin, occur at Rewasa in Rajputana and contain pebbles of white quartz, pale and dark grey quartzite, white grit and mica-schist, in a matrix of biotite and chlorite and euhedral grains of magnetite. The pebbles are flattened along the foliation planes. Dr. J. A. Dunn[5] has recently ascribed a sedimentary origin to sheared conglomerates, similar to the Gangpur ones, occurring in North Singhbhum. He considers them to have been deposited during periods of inter-volcanic erosion.

According to Sir Henry Hayden[6], the Lower Haimantas in the valley of the Lipak river show a crush conglomerate. The quartz pebbles found in a matrix of biotite-schist are believed by him to represent portions of veins which have been broken up by intense crushing. A basic dyke in the neighbourhood is also said to have been similarly converted into strings of pebbles. These occurrences have, therefore, been regarded as truly autoclastic.

Several occurrences of conglomerate have been reported from Mysore. Those which were examined prior to about 1908 were

[1] *Mem. Geol. Surv. Ind.*, XXV, pp. 80, 87, 105-107, 140, (1895).
[2] *Op. cit.*, XXXVII, Pt. 2, p. 311, (1909).
[3] *Rec. Geol. Surv. Ind.*, XXXIV, p. 108, (1906).
[4] *Mem. Geol. Surv. Ind.*, XLV, Pt. 1, pp. 17, 22, (1917).
[5] *Op. cit.*, LIV, pp. 32-35, (1929).
[6] *Op. cit*, XXXVI, Pt. 1, pp. 11-12, (1912).

described as sedimentary, but since then, under Dr. W. F. Smeeth's inspiration, all of them have been one by one transferred to the autoclastic group. Those found later have all been described as autoclastic. Mr. C. S. Middlemiss[1] has remarked on the vigour and unanimity with which the autoclastic origin has been advocated and adopted, and on the unacceptability of these conclusions at least in their entirety. He has also pointed out that Dr. Smeeth himself was apparently getting rather tired of the 'hornet's nest' of autoclastic conglomerates which he had raised.[2] Among these, particular mention may be made of the Kaldurga conglomerate. Bruce Foote[3] thought that they were clastic. Mr. H. K. Slater[4] left their origin as doubtful, but Dr. Smeeth[5] gave a decisive opinion, favouring the autoclastic origin, which was later confirmed by Mr. P. Sampat Iyengar[6] as the result of a very detailed study. In his annual report for the year 1909-10, Dr. Smeeth[7] describes briefly the Mallapanhalli, the Gudad-Rangavanhalli (G. R.) formation, the Aimangala and the Kolar conglomerates, to all of which he assigns an autoclastic origin. Other rocks of the same nature have been studied by Messrs. H. K. Slater[8], P. Sampat Iyengar[9], B. Jayaram[10], A. M. Sen[11], and B. Balaji Rao[12] in different parts of Mysore.

DISCUSSION AND CONCLUSION.

The criteria for distinguishing autoclastic from crush conglomerates of sedimentary origin are generally difficult of application in the field where highly folded and metamorphosed sediments are concerned. Crush conglomerates generally occur at the junction of dissimilar rocks—dissimilar particularly in their physical characters, such as hardness and plasticity under stress. The harder rock is broken up into fragments, while the softer is milled and

[1] Presidential address to the Geology Section, Fourth Indian Science Congress, Bangalore. *Proc. As. Soc. Bengal*, N. S. XIII, p. cxcvi, (1917).
[2] *Rec. Mys. Geol. Dept.*, XII, p. 38, (1912).
[3] *Rec. Geol. Surv. Ind.*, XV, p. 195, (1882).
[4] *Rec. Mys. Geol. Dept.*, VII, Pt. 2, pp. 1-4, (1906).
[5] *Op. cit.*, XIV, p. 25, (1915).
[6] *Op. cit.*, XV, Pt. 2, pp. 107-116, (1916).
[7] *Op. cit.*, XI, pp. 1-67, (1910).
[8] *Op. cit.*, XII, Pt. 2, 26-29, (1912).
[9] *Op. cit.*, XII, Pt. 2, pp. 54-55, (1912).
[10] *Op. cit.*, XIV, pp. 93-94, (1915).
[11] *Op. cit.*, XIV, pp. 150-152, (1915).
[12] *Op. cit.*, XXV, p. 88, (1926).

foliated and forms the matrix in which the fragments of the former get lodged. Under the intense crushing and shearing to which the ancient rocks have generally been subjected, the original depositional structures, if present, would obviously have been more or less obliterated. If the pebbles can be proved to have been contributed by rocks of later age than the matrix in which they are found, the rock must evidently be a pseudo-conglomerate. The presence of igneous rocks of an age later than that of the matrix is useful in this connection, particularly if uncrushed bands of these lie contiguously with the crushed portion. This is exemplified in the case of the Spiti and the Kaldurga rocks which have been referred to above.

In the conglomerates dealt with in the present paper, the Durghati Piparia rock (C 1) seems to the writer to be an undoubted sedimentary conglomerate. Among the occurrences described, this shows the least amount of crushing. At other places along the same band, more crushed portions can be seen. The occurrence at Sahdar (C 3) shows semi-angular pebbles of iron-ore-quartzite. There are no rocks of this nature in the immediate neighbourhood. It seems reasonable to think that the fragments have been transported by water from their original source, wherever it might have been. Leaving aside type D, which is of the nature of an igneous breccia, the other rocks in the Jubbulpore area show progressive stages in crushing.

In the Gangpur area, the pebbles of the conglomerate are found to be of varied nature—biotite-schist, quartzite, tourmaline-quartz-rock, and rarely granite. In the field, the conglomerates have the appearance of those due to epiclastic origin. No example has been found in which an uncrushed vein or band passes into a string of pebbles in the conglomerate. In a few cases, however, as in the minor lenticular bands amidst the quartzites of the Gamburu-Durgapata ridge, the conglomerates may be autoclastic, as the pebbles in some cases are seen to be identical in composition with the matrix.

From this study it is concluded that practically all the cases represent conglomerates of original sedimentary origin. In places, the sedimentary characters have been obscured by intense crushing and shearing. The breccia at Amehta is of a special type, while a few minor occurrences in the south-east of Gangpur seem to be autoclastic.

EXPLANATION OF PLATES.

PLATE 26, FIG. 1.—Conglomerate with large rounded pebbles, Durghati Piparia, Jubbulpore. Specimen 44·41. Negative 4370.

FIG. 2.—Conglomerate with sub-angular pebbles, Bhitrigarh, Jubbulpore. Specimen 44·42. Negative 4372.

PLATE 27, FIG. 1.—Conglomerate with pebbles of dark, banded iron-ore–quartzite, Sahdar, Jubbulpore. Specimen 44·44. Negative 4373.

FIG. 2.—Brecciated dark quartzite cemented by white quartz, ridge near Amehta, Jubbulpore. Specimen 44·39. Negative 4371.

PLATE 28, FIG. 1.—Schistose conglomerate. Parallelism of muscovite flakes. Crossed nicols. × 25. Section 19995. Negative 1787.

FIG. 2.—Showing coarser quartz surrounded by finer granulated quartz. Crossed nicols. × 25. Section 21389. Negative 1790.

FIG. 3.—Showing patches of phyllite. Crossed nicols. ×25. Section 19838. Negative 1785.

FIG. 4.—Showing patches of phyllite and a granite pebble with plagioclase. Crossed nicols. ×25. Section 19902. Negative 1786.

PLATE 29, FIG. 1.—Coarse pebble with a vein of quartz surrounded by finely granulated quartz. Crossed nicols. ×25. Section 21933. Negative 1782.

FIG. 2.—Showing pebble of banded iron-ore–quartzite. Crossed nicols. ×25. Section 21935. Negative 1784.

INDEX TO RECORDS, VOLUME LXVII.

B

D

E

H

O

R

RECORDS

OF

THE GEOLOGICAL SURVEY OF INDIA.

RECORDS

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1934

CONTENTS.

PART 1.

PART 2.

PART 3.

PART 4.

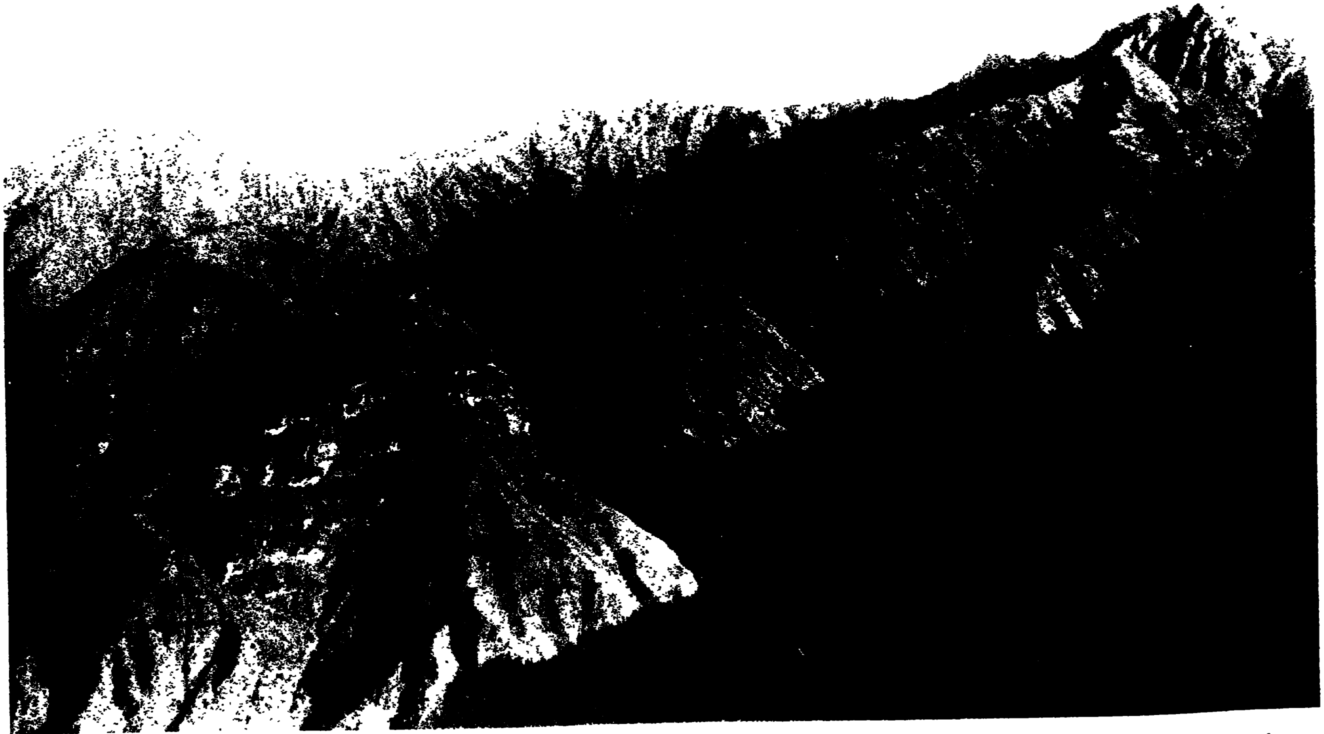
Q

LIST OF PLATES, VOLUME LXVII.

MGPIO—M—VIII-4-20—12-4-34—850.

J. B. Auden, Photo. G. S. I., Calcutta.

KAMLI DHAR AND GIRI RIVER. FROM NEAR CHANDNI (HEIGHT DIFFERENCE 4,750 FEET). MANDHALI, JAUNSAR AND KROL SERIES.



J. B. Auden, Photo. G. S. I., Calcutta.

SYNCLINE OF UPPER TAL QUARTZITES AND SHALES,

J. B. Auden, Photo. *G. S. I., Calcutta.*

OVERFOLD IN KROL D STAGE. VIEW OF MANGARH VILLAGE, WITH BHARAN, SAINBAR, AND 6,687 FEET HILLS IN THE DISTANCE.

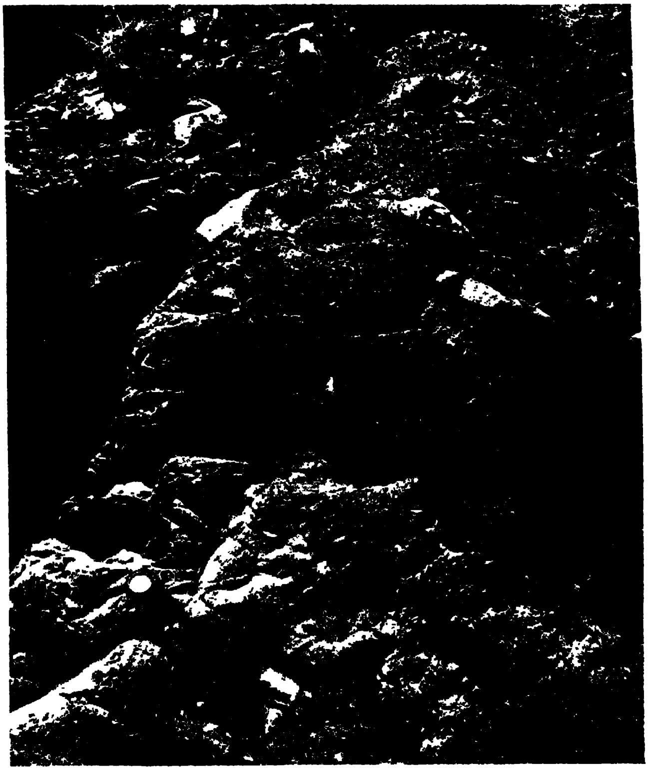
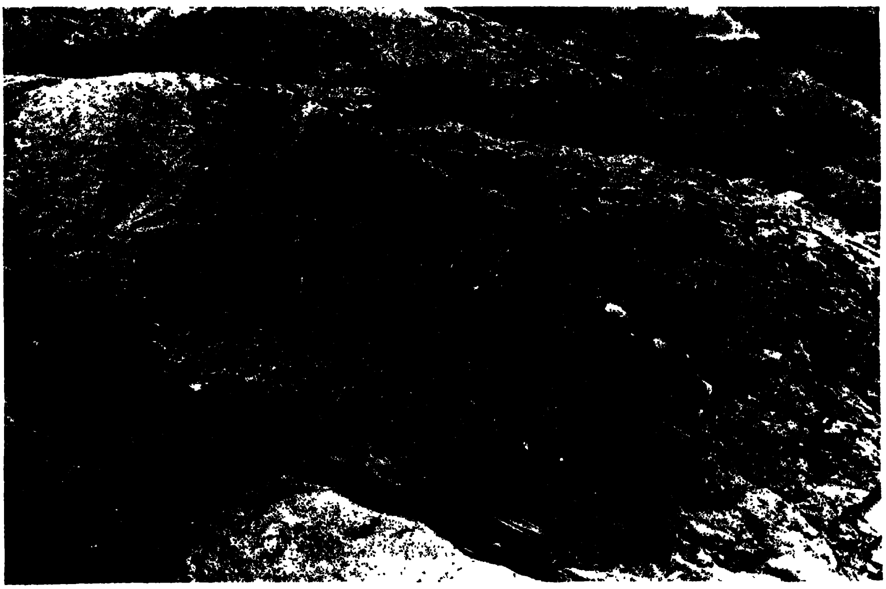


FIG. 1. BLAINI BOULDER BED, CONFLUENCE OF BLAINI AND GAMBHAR RIVERS.

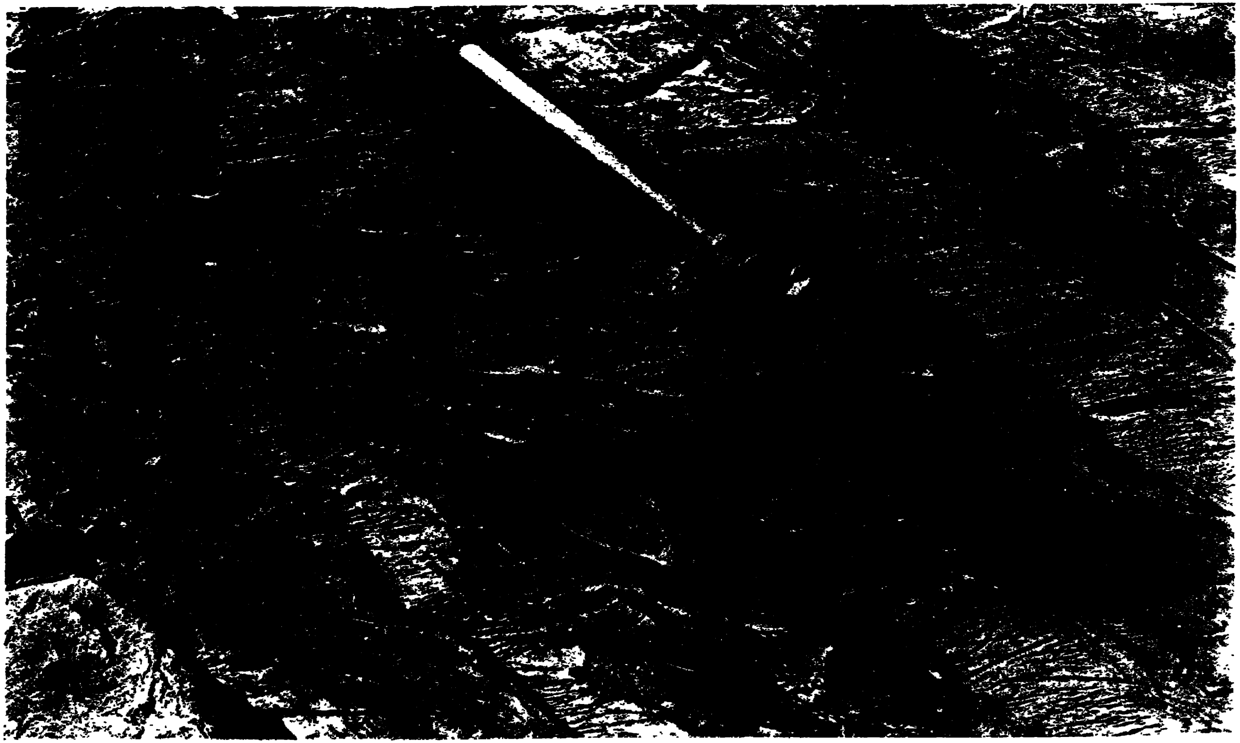


J. B. Auden, Photos.

G. S. I., Calcutta.

FIG. 1. FAULT ZONE IN KROL A LIMESTONES AND SHALES, GIRI RIVER, THREE-QUARTERS OF A MILE NORTH OF DADAHU.

FIG. 2. STEEPLY TILTED RIPPLE-MARKED JAUNSAR QUARTZITES, GIRI RIVER, ONE MILE BELOW NARAIL.



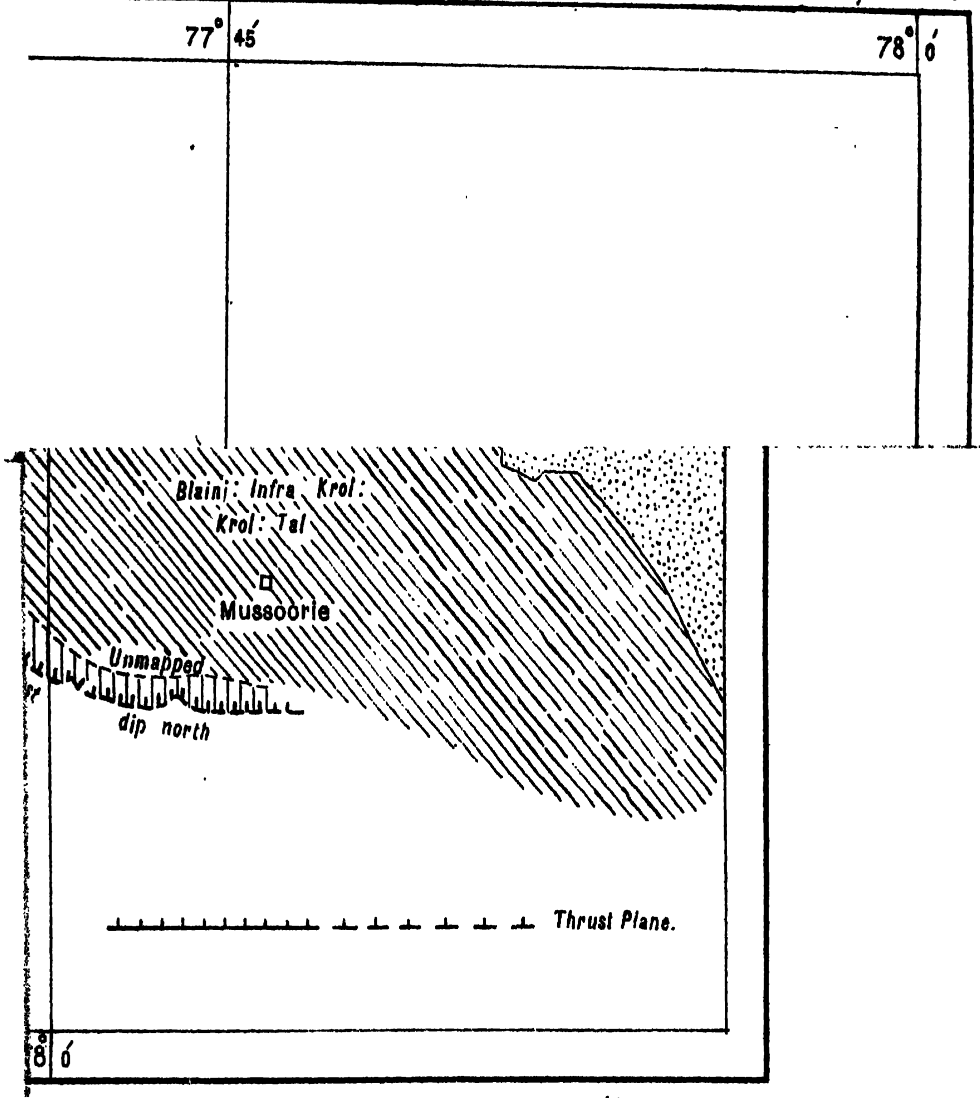
J. B. Auden, Photo. G. S. I. Calcutta.

DEFORMATION OF KROL A LIMESTONE AND SHALE BY FLOW, ONE-QUARTER OF A MILE W. S. W. OF HEIGHT 3,278 FEET, NERA (NEWALI) NALA.

G. S. I., Calcutta.

J. B. Auden, Photo.

DARK, CURRENT-BEDDED, SANDY LIMESTONE OVERLYING PALE QUARTZITES, UPPER TALS. CURRENT-BEDDING CONCAVE UPWARDS. NIGALI DHAR, THREE-QUARTERS OF A MILE NORTH-EAST OF KOTI DHAMAN.



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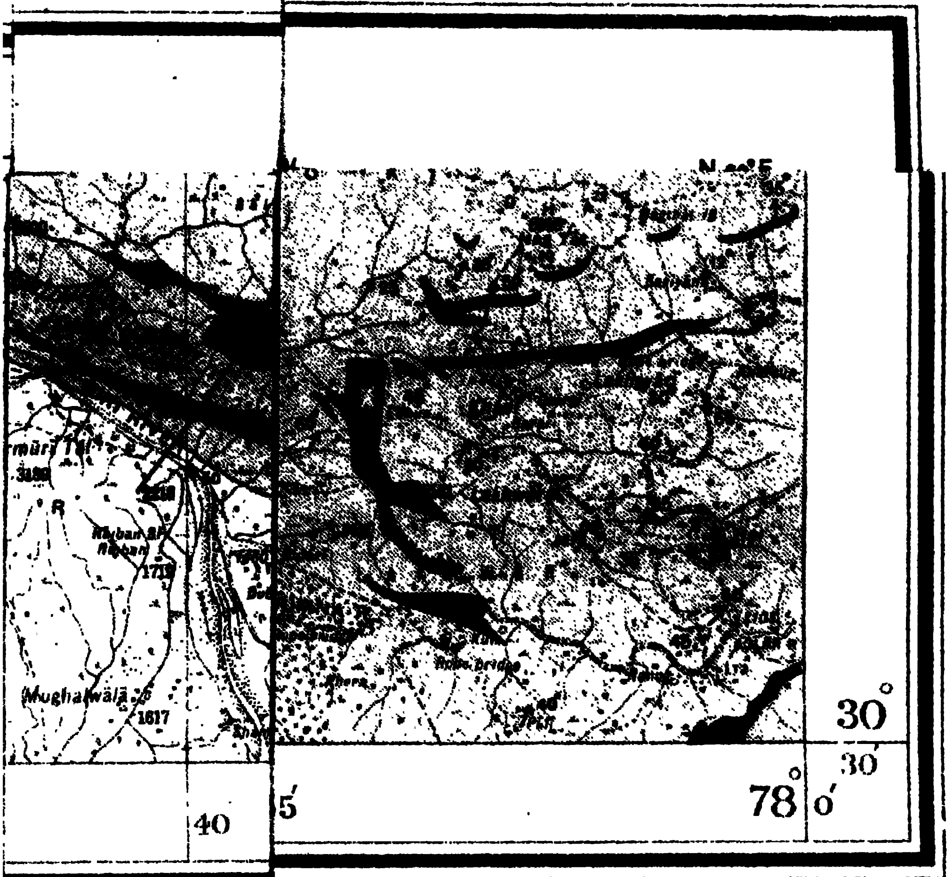
s, Vol. LXVII, Pl. 25.



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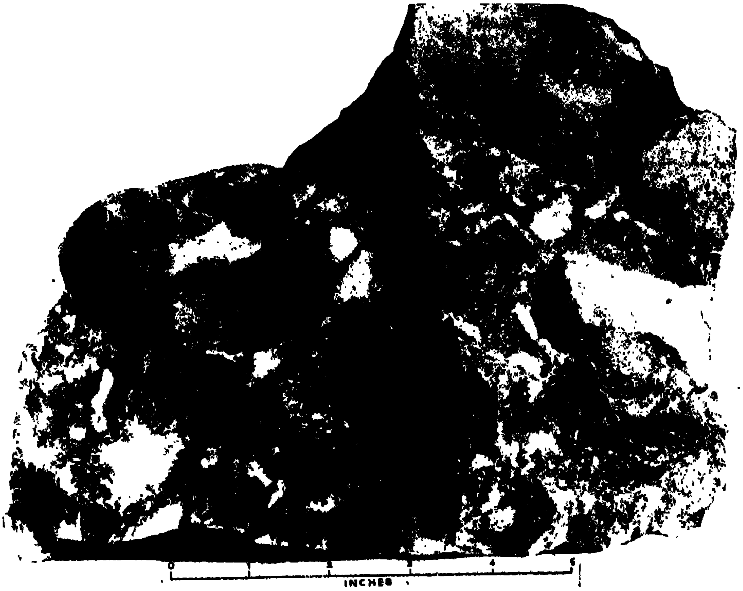
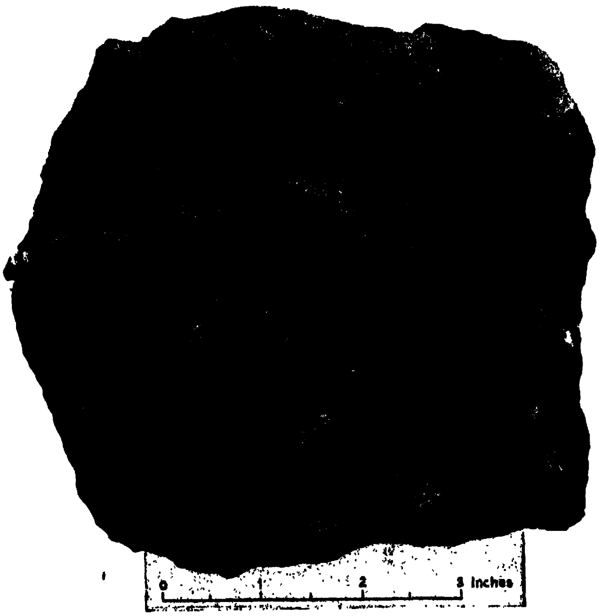


FIG. 1. CONGLOMERATE WITH LARGE ROUNDED PEBBLES, DURGHATI PIPARIA, JUBBULPORE.



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G. S. I., Calcutta.

FIG. 2. CONGLOMERATE WITH SUB-ANGULAR PEBBLES,

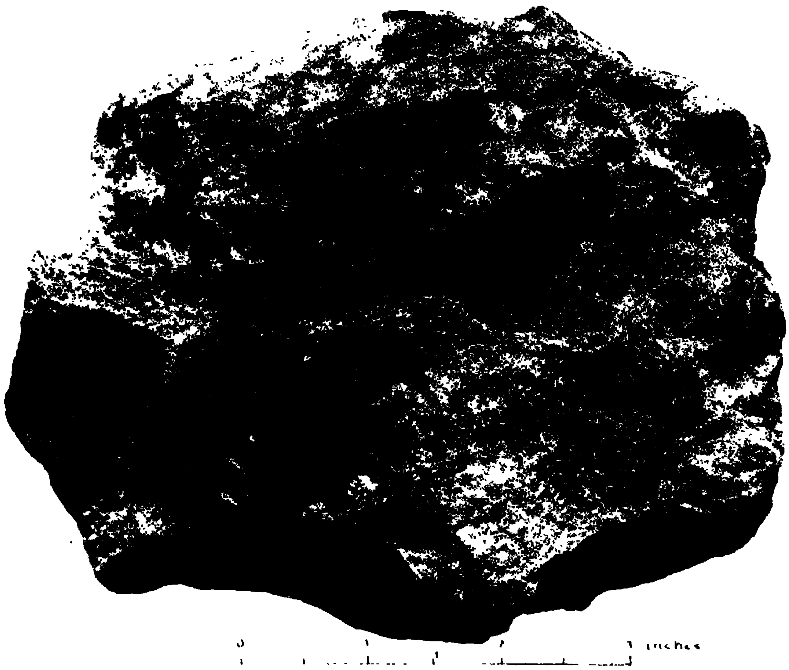

FIG. 1. CONGLOMERATE WITH PEBBLES OF DARK, BANDED IRON-ORE-QUARTZITE, SAHDAR, JUBBULPORE.

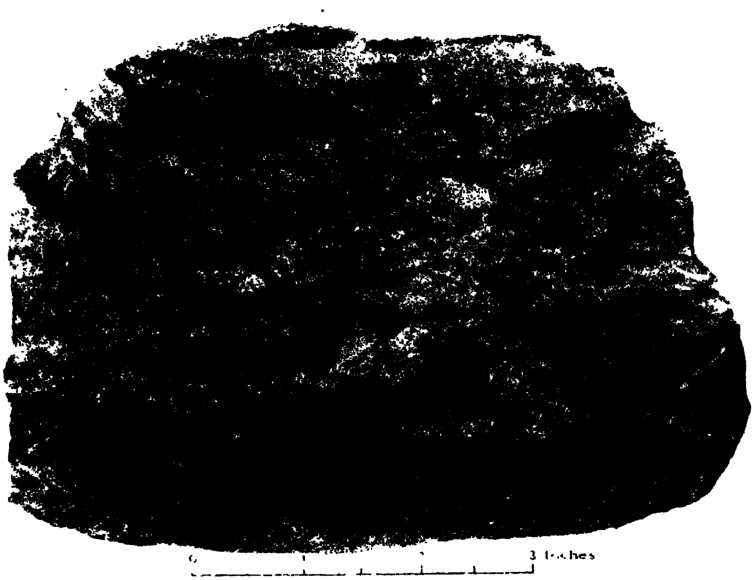

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FIG. 2. BRECCIATED DARK QUARTZITE, CEMENTED BY WHITE QUARTZ,

Records, Vol. LXVII, Pl. 28.

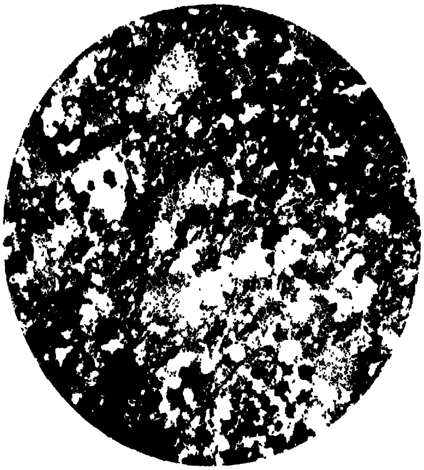


FIG. 1. SCHISTOSE CONGLOMERATE SHOWING PARALLELISM AMONG MUSCOVITE FLAKES.
Crossed nicols (× 21).

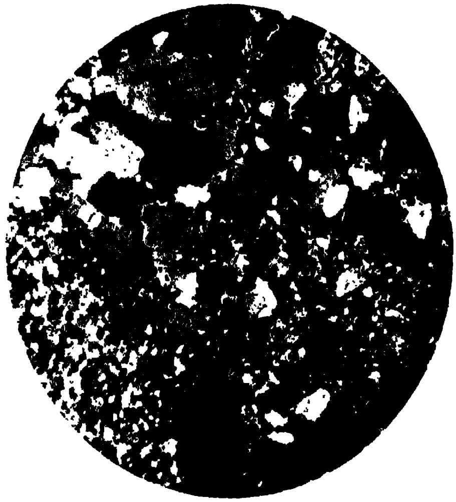
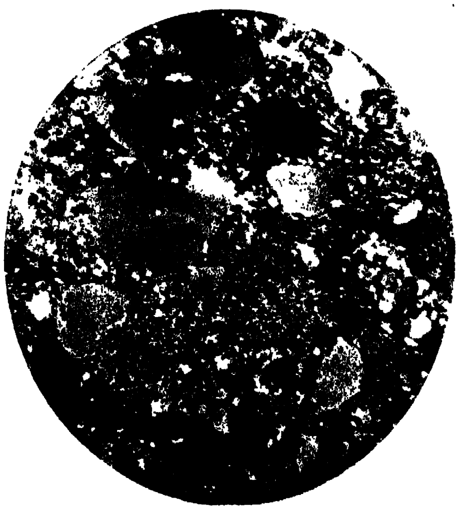


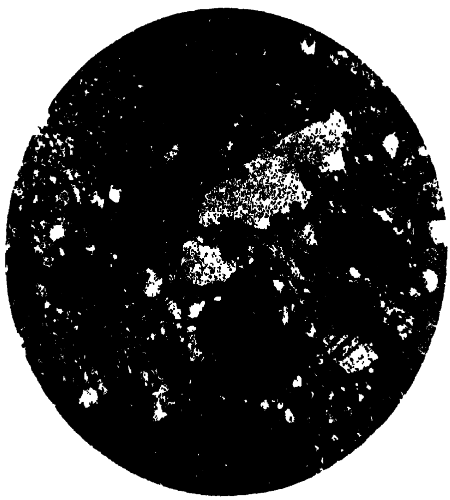
FIG. 2. SHOWING COARSER QUARTZ SURROUNDED BY FINER GRANULATED QUARTZ.
Crossed nicols (× 21).



M. S. Krishnan & P. L. Dutt, Photomicros.

FIG. 3. SHOWING PATCHES OF PHYLLITE.

Crossed nicols (× 21).



G. S. I., Calcutta.

FIG. 4. SHOWING PATCHES OF PHYLLITE AND A PEBBLE OF GRANITE WITH PLAGIOCLASE.
Crossed nicols (× 21).

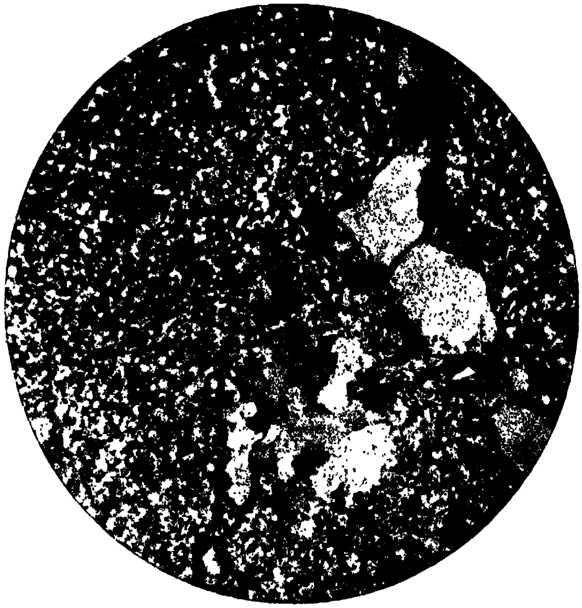
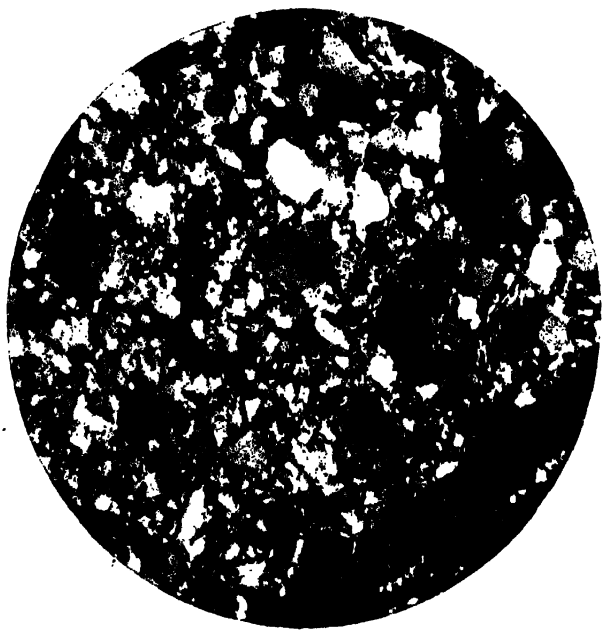


FIG. 1. SHOWING A COARSE PEBBLE, VEINS AND FINELY GRANULATED MATRIX, ALL OF QUARTZ. Crossed nicols (× 25).



M. S. Krishnan & P. L. Dutt, Photomicros. *G. S. I., Calcutta.*

FIG. 2. SHOWING PART OF A DARK BANDED IRON-ORE-QUARTZITE PEBBLE.

Vol. X, 1877.

Part 1 (out of print).—Annual report for 1876. Geological notes on Great Indian Desert between Sind and Rajputana. Cretaceous genus Omphalia near Nameho lake, Tibet, about 75 miles north of Lhassa. Estheria in Gondwana formation. Vertebrata from Indian tertiary and secondary rocks. New Emydine from the upper tertiaries of Northern Punjab. Observations on under-ground temperature.

Part 2 (out of print).—Rocks of the Lower Godavari. 'Atgarh Sandstones' near Cuttack. Fossil floras in India. New or rare mammals from the Siwaliks. Aravali series in North-Eastern Rajputana. Borings for coal in India. Geology of India.

Part 3 (out of print).—Tertiary zone and underlying rocks in North-West Punjab. Fossil floras in India. Erratics in Potwar. Coal explorations in Darjiling district. Limestones in neighbourhood of Barakar. Forms of blowing machine used by smiths of Upper Assam. Analyses of Raniganj coals.

Part 4 (out of print).—Geology of Mahanadi basin and its vicinity. Diamonds, gold, and lead ores of Sambalpur district. 'Eryon Comp. Barrovensis', McCoy, from Sripermatur group near Madras. Fossil floras in India. The Blaini group and 'Central Gneiss' in Simla, Himalayas. Tertiaries of North-West Punjab. Genera Chœromeryx and Rhagatherium.

Vol. XI, 1878.

Part 1.—Annual report for 1877. Geology of Upper Godavari basin, between river Wardha and Godavari, near Sironcha. Geology of Kashmir, Kishtwar, and Pangi. Siwalik mammals. Palæontological relations of Gondwana system. 'Erratics in Punjab.'

Part 2 (out of print).—Geology of Sind (second notice). Origin of Kumaun lakes. Trip over Milam Pass, Kumaun. Mud volcanoes of Ramri and Cheduba. Mineral resources of Ramri, Cheduba and adjacent islands.

Part 3 (out of print).—Gold industry in Wynaad. Upper Gondwana series in Trichinopoly and Nellore-Kistna districts. Senarmontite from Sarawak.

Part 4.—Geographical distribution of fossil organisms in India. Submerged forest on Bombay Island.

Vol. XII, 1879.

Part 1.—Annual report for 1878. Geology of Kashmir (third notice). Siwalik mammalia, Siwalik beds. Tour through Hangrang and Spiti. Mud eruption in Ramri Island (Arakan). Braunite, with Rhodonite, from Nagpur, Central Provinces. Palæontological notes from Satpura coal-basin. Coal importations into India.

Part 2 (out of print).—Mohpani coal-field. Pyrolusite with Psilomelane at Gosalpur, Jabalpur district. Geological reconnaissance from Indus at Kushalgarh to Kurram at Thal on Afghan frontier. Geology of Upper Punjab.

Part 3 (out of print).—Geological features of northern Madura, Pudukota State, and southern parts of Tanjore and Trichinopoly districts included within limits of sheet 80 of Indian Atlas. Cretaceous fossils from Trichinopoly district, collected in 1877-78. Sphenophyllum and other Equisetaceæ with reference to Indian form Trizygia Speciosa, Royle (Sphenophyllum Trizygia, Ung.). Mysorin and Atacamite from Nellore district. Corundum from Khasi Hills. Joga neighbourhood and old mines on Norbadda.

Part 4.—'Attock Slates' and their probable geological position. Marginal bone of undescribed tortoise, from Upper Siwaliks, near Nila, in Potwar, Punjab. Geology of North Arcot district. Road section from Murree to Abbottabad.

Vol. XIII, 1880.

Part 1.—Annual report for 1879. Geology of Upper Godavari basin in neighbourhood of Sironcha. Geology of Ladak and neighbouring districts. Teeth of fossil fishes from Ramri Island and Punjab. Fossil genera Nöggerathia, Stbg., Nöggerathiopsis, Fstm., and Rhiptozamites, Schmalh., in palæozoic and secondary rocks of Europe, Asia and Australia. Fossil plants from Kattywar, Shekh Budin, and Sirgujah. Volcanic foci of eruption in Konkan.

Part 2.—Geological notes. Palæontological notes on lower trias of Himalayas. Artesian wells at Pondicherry, and possibility of finding sources of water-supply at Madras.

Part 3.—Kumaun lakes. Celt of palæolithic type in Punjab. Palæontological notes from Karharbari and South Rewa coal-fields. Correlation of Gondwana flora with other floras. Artesian wells at Pondicherry. Salt in Rajputana. Gas and mud eruptions on Arakan coast on 12th March 1879 and in June 1843.

Part 4 (out of print).—Pleistocene deposits of Northern Punjab, and evidence they afford of extreme climate during portion of that period. Useful minerals of Arvali region. Correlation of Gondwana flora with that of Australian coal-bearing system. Reh or alkali soils and saline well waters. Reh soils of Upper India. Naini Tal landslip, 18th September 1880.

Vol. XIV, 1881.

Part 1.—Annual report for 1880. Geology of part of Dardistan, Baltistan, and neighbouring districts. Siwalik carnivora. Siwalik group of Sub-Himalayan region. South Rewah Gondwana basin. Ferruginous beds associated with basaltic rocks of north-eastern Ulster, in relation to Indian laterite. Rajmahal plants. Travelled blocks of the Punjab. Appendix to 'Palæontological notes on lower trias of Himalayas'. Mammalian fossils from Perim Island.

Part 2 (out of print).—Nahan-Siwalik unconformity in North-Western Himalaya. Gondwana vertebrates. Ossiferous beds of Hundes in Tibet. Mining records and mining record office of Great Britain; and Coal and Metalliferous Mines Act of 1872 (England). Cobaltite and danatite from Khetri mines, Rajputana; with remarks on Jaipurite (Syepoorite) Zinc-ore (Smithsonite and Blende) with barytes in Karnul districts, Madras. Mud eruption in island of Cheduba.

Part 3 (out of print).—Artesian borings in India. Oligoclase granite at Wangtu on Sutlej, North-West Himalayas. Fish-plate from Siwaliks. Palæontological notes from Hazaribagh and Lohardagga districts. Fossil carnivora from Siwalik hills.

Part 4 (out of print).—Unification of geological nomenclature and cartography. Geology of Aravali region, central and eastern. Native antimony obtained at Pulo Obin, near Singapore. Turgite from Juggiapett, Kistnah District, and zinc carbonate from Karnul, Madras. Section from Dalhousie to Pangi, *viâ* Sach Pass. South Rewah Gondwana basin. Submerged forest on Bombay Island.

Vol. XV, 1882.

Part 1 (out of print).—Annual report for 1881. Geology of North-West Kashmir and Khagan. Gondwana labyrinthodonts (Siwalik and Jamna mammals). Geology of Dalhousie, North-West Himalaya. Palm leaves from (tertiary) Murree and Kasauli beds in India. Iridosmine from Noa-Dihing river, Upper Assam, and Platinum from Chutia Nagpur. On (1) copper mine near Yongri hill, Darjiling district: (2) arsenical pyrites in same neighbourhood; (3) kaolin at Darjiling. Analyses of coal and fire-clay from Makum coal-field, Upper Assam. Experiments on coal of Pind Dadun Khan, Salt-range, with reference to production of gas, made April 29th, 1881. International Congress of Bologna.

Part 2 (out of print).—Geology of Travancore State. Warkilli beds and reported associated deposits at Quilon, in Travancore. Siwalik and Narbada fossils. Coal-bearing rocks of Upper Rer and Mand rivers in Western Chutia Nagpur. Pench river coal-field in Chhindwara district, Central Provinces. Boring for coal at Engsein, British Burma. Sapphires in North-Western Himalaya. Eruption of mud volcanoes in Cheduba.

Part 3 (out of print).—Coal of Mach (Much) in Bolan Pass, and of Sharigh on Harnai route between Sibi and Quetta. Crystals of stilbite from Western Ghats, Bombay. Traps of Darang and Mandi in North-Western Himalayas. Connexion between Hazara and Kashmir series. Umaria coal-field (South Rewah Gondwana basin). Daranggiri coal-field, Garo Hills, Assam. Coal in Myanoung division, Henzada district.

Part 4 (out of print).—Coal-fields of Mysore. Borings for coal at Beddadanol, Godavari district, in 1874. Supposed occurrence of coal on Kistna.

Vol. XVI, 1883.

Part 1.—Annual report for 1882. Richthofenia, Kays. (Anomia Lawrenciana, Koninck). Geology of South Travancore. Geology of Chamba. Basalts of Bombay.

Part 2 (out of print).—Synopsis of fossil vertebrata of India. Bijori Labyrinthodont Skull of Hippotherium antilopinum. Iron ores, and subsidiary materials for manufacture of iron, in north-eastern part of Jabalpur district. Laterite and other manganese-ore occurring at Gosulpore, Jabalpur district. Umaria coal-field.

Part 3 (out of print).—Microscopic structure of some Dalhousie rocks. Lavas of Aden. Probable occurrence of Siwalik strata in China and Japan. Mastodon angustidens in India. Traverse between Almora and Mussoorree. Cretaceous coal-measures at Borsora in Khasia Hills, near Laour in Sylhet.

Part 4 (out of print).—Palæontological notes from Daltonganj and Hutar coal-fields in Chota Nagpur. Altered basalts of Dalhousie region in North-Western Himalayas. Microscopic structure of some Sub-Himalayan rocks of tertiary age. Geology of Jaunsar and Lower Himalayas. Traverse through Eastern Khasia, Jaintia, and North Cachar Hills. Native lead from Maulmain and chromite from the Andaman Islands. Fiery eruption from one of the mud volcanoes of Cheduba Island, Arakan. Irrigation from wells in North-Western Provinces and Oudh.

Vol. XVII, 1884.

Part 1 (out of print).—Annual report for 1883. Smooth-water anchorages or mud-banks of Narrakal and Alleppy on Travancore coast. Billa Surgam and other caves in Karnool district. Geology of Chuari and Sihunta parganas of Chamba. Lyttonia, Waagen, in Kuling series of Kashmir.

Part 2 (out of print).—Earthquake of 31st December 1881. Microscopic structure of some Himalayan granites and gneissose granites. Choi coal exploration. Re-discovery of fossils in Siwalik beds. Mineral resources of Andaman Islands in neighbourhood of Port Blair. Intertrappean beds in Deccan and Laramie group in Western North America.

Part 3 (out of print).—Microscopic structure of some Aravali rocks. Section along Indus from Peshawar Valley to Salt-range. Sites for boring in Raigarh-Hingir coal-field (first notice). Lignite near Raipoto, Central Provinces. Turquoise mines of Nishâpûr, Khorassan. Fiery eruption from Minbyin mud vulcano of Cheduba Island, Arakan. Langrin coal-field, South-West Khasia Hills. Umaria coal-field.

Part 4 (out of print).—Geology of part of Gangasulan pargana of British Garhwal. Slates and schists imbedded in gneissose granite of North-West Himalayas. Geology of Takht-i-Suleiman. Smooth-water anchorages of Travancore coast. Auroferous sands of the Subansiri river, Pondicherry lignite and phosphatic rocks at Musuri. Billa Surgam caves.

Vol. XVIII, 1885.

Part 1 (out of print).—Annual report for 1884. Country between Singareni coal-field and Kistna river. Geological sketch of country between Singareni coal-field and Hyderabad. Coal and limestone in Doigrung river near Golaghat, Assam. Homotaxis, as illustrated from Indian formations. Afghan field notes.

Part 2.—Fossiliferous series in Lower Himalaya, Garhwal. Age of Mandhali series in Lower Himalaya. Siwalik camel (Camelus Antiquus, nobis ex Falc. and Caut. MS.). Geology of Chamba. Probability of obtaining water by means of artesian wells in plains of Upper India. Artesian sources in plains of Upper India. Geology of Aka Hills. Alleged tendency of Arakan mud volcanoes to burst into eruption most frequently during rains. Analyses of phosphatic nodules and rock from Mussooree.

Part 3 (out of print).—Geology of Andaman Islands. Third species of Merycopotamus. Percolation as affected by current. Pirthala and Chandpur meteorites. Oil-wells and coal in Thayetmyo district, British Burma. Antimony deposits in Maulmain district. Kashmir earthquake of 30th May 1885. Bengal earthquake of 14th July 1885.

Part 4 (out of print).—Geological work in Chhattisgarh division of Central Provinces. Bengal earthquake of 14th July 1885. Kashmir earthquake of 30th May 1885. Excavations in Billa Surgam caves. Nepaulite. Sabetmahet meteorite.

Vol. XIX, 1886.

Part 1 (out of print).—Annual report for 1885. International Geological Congress of Berlin. Palæozoic Fossils in Olive group of Salt-range. Correlation of Indian and Australian Coal-bearing beds. Afghan and Persian Field-notes. Section from Simla to Wangtu, and petrological character of Ambhibolites and Quartz-Diorites of Sutlej valley.

Part 2 (out of print).—Geology of parts of Bellary and Anantapur districts. Geology of Upper Dehing basin in Singpho Hills. Microscopic characters of eruption rocks from Central Himalayas. Mammalia of Karnul Caves. Prospects of finding coal in Western Rajputana. Olive group of Salt-range. Boulder-beds of Salt-range. Gondwana Homotaxis.

Part 3 (out of print).—Geological sketch of Vizagapatam district, Madras. Geology of Northern Jesalmer. Microscopic structure of Malani rocks of Arvali region. Malanjkhandi copper-ore in Balaghat district, C. P.

Part 4 (out of print).—Petroleum in India. Petroleum exploration at Khátan. Boring in Chhattisgarh coal-fields. Field-notes from Afghanistan: No. 3, Turkistan. Fiery eruption from one of the mud volcanoes of Cheduba Island, Arakan. Nammianthal aerolite. Analysis of gold dust from Meza valley, Upper Burma.

Vol. XX, 1887.

Part 1 (out of print).—Annual report for 1886. Field-notes from Afghanistan: No. 4, from Turkistan to India. Physical geology of West British Garhwal; with notes on a route traversed through Jaunsar-Bawar and Tiri-Garhwal. Geology of Garo Hills. Indian image-stones. Soundings recently taken off Barren Island and Narcondam. Talchir boulder-beds. Analysis of Phosphatic Nodules from Salt-range, Punjab.

Part 2.—Fossil vertebrata of India. Echinoides of cretaceous series of Lower Narbada Valley. Field-notes: No. 5—to accompany geological sketch map of Afghanistan and North-Eastern Khorassan. Microscopic structure of Rajmahal and Deccan traps. Dolerite of Chor. Identity of Olive series in east, with speckled sandstone in west, of Salt-range in Punjab.

Part 3.—Retirement of Mr. Medlicott. J. B. Mushketoff's Geology of Russian Turkistan. Crystalline and metamorphic rocks of Lower Himalaya, Garhwal, and Kumaun, Section I. Geology of Simla and Jutogh. 'Lalitpur' meteorite.

Part 4 (out of print).—Points in Himalayan geology. Crystalline and Metamorphic rocks of Lower Himalaya, Garhwal, and Kumaon, Section II. Iron industry of western portion of Raipur. Notes on Upper Burma. Boring exploration in Chhattisgarh coal-field (Second notice). Pressure Metamorphism, with reference to foliation of Himalayan Gneissose Granite. Papers on Himalayan Geology and Microscopic Petrology.

Vol. XXI, 1888.

Part 1.—Annual report for 1887. Crystalline and metamorphic rocks of Lower Himalaya, Garhwal, and Kumaun, Section III. Birds'-nest of Elephant Island, Mergui Archipelago. Exploration of Jesalmer, with a view to discovery of coal. Facetted pebble from boulder-bed ('speckled sandstone') of Mount Chel in Salt-range, Punjab. Nodular stones obtained off Colombo.

Part 2 (out of print).—Award of Wollaston Gold Medal, Geological Society of London, 1888. Dharwar System in South India. Igneous rocks of Raipur and Balaghat, Central Provinces. Sangar Marg and Mohowgale coal-fields, Kashmir.

Part 3 (out of print).—Manganese Iron and Manganese Ores of Jabalpur. 'The Carboniferous Glacial Period.' Pre-tertiary sedimentary formations of Simla region of Lower Himalayas.

Part 4 (out of print).—Indian fossil vertebrates. Geology of North-West Himalayas Blown-sand rock sculpture. Nummulites in Zanskar. Mica traps from Barakar and Raniganj.

Vol. XXII, 1889.

Part 1 (out of print).—Annual report for 1888. Dharwar System in South India. Wajra Karur diamonds, and M. Chaper's alleged discovery of diamonds in pegmatite. Generic position of so-called Plesiosaurus indicus. Flexible sandstone or Itacolumite, its nature, mode of occurrence in India, and cause of its flexibility. Siwalik and Narbada Chelonia.

Part 2 (out of print).—Indian Steatite. Distorted pebbles in Siwalik conglomerate, "Carboniferous Glacial Period." Notes on Dr. W. Waagen's "Carboniferous Glacial Period". Oil-fields of Twingoung and Beme, Burma Gypsum of Nehal Nadi, Kumaun. Materials for pottery in neighbourhood of Jabalpur and Umaria.

Part 3 (out of print).—Coal outcrops in Sharigh Valley, Baluchistan. Trilobites in Neobolus beds of Salt-range. Geological notes. Cherra Poonjee coal-fields, in Khasia Hills. Cobaltiferous Matt from Nepál. President of Geological Society of London on International Geological Congress of 1888 Tin-mining in Mergui district.

Part 4 (out of print).—Land-tortoises of Siwaliks. Pelvis of a ruminant from Siwaliks. Assays from Sambhar Salt-Lake in Rajputana. Manganiferous iron and Manganese Ores of Jabalpur. Palagonite-bearing traps of Rájmahál hills and Deccan. Tin-smelting in Malay Peninsula. Provincial Index of Local Distribution of Important Minerals, Miscellaneous Minerals, Gem Stones and Quarry Stones in Indian Empire: Part 1.

Vol. XXIII, 1890.

Part 1 (out of print).—Annual report for 1889. Lakadong coal-fields, Jaintia Hills. Pectoral and pelvic girdles and skull of Indian Dicynodonts. Vertebrate remains from Nagpur district (with description of fish-skull). Crystalline and metamorphic rocks of Lower Himalayas, Garhwál and Kumaun, Section IV. Bivalves of Olive-group, Salt-range. Mud-banks of Travancore coasts.

Part 2 (out of print).—Petroleum explorations in Harnai district, Baluchistan. Sapphire Mine of Kashmir. Supposed Matrix of Diamond at Wajra Karur, Madras. Sonapet Gold-field. Field-notes from Shan Hills (Upper Burma). New species of Syringosphæridæ.

Part 3 (out of print).—Geology and Economic Resources of Country adjoining Sind-Pishin Railway between Sharigh and Spintangi, and of country between it and Khattan. Journey through India in 1888-89, by Dr. Johannes Walther. Coal-fields of Lairungao, Maosandram, and Mao-be-lar-kar, in the Khasi Hills. Indian Steatite. Provincial Index of Local Distribution of Important Minerals, Miscellaneous Minerals, Gem Stones, and Quarry Stones in Indian Empire.

Part 4 (out of print).—Geological sketch of Naini Tal; with remarks on natural conditions governing mountain slopes. Fossil Indian Bird Bones. Darjiling Coal between Lisu and Ramthi rivers. Basic Eruptive Rocks of Kadapah Area. Deep Boring at Lucknow. Coal Seam of Dore Ravine, Hazara.

Vol. XXIV, 1891.

Part 1 (out of print).—Annual report for 1890. Geology of Salt-range of Punjab, with re-considered theory of Origin and Age of Salt-Marl. Graphite in decomposed Gneiss (Laterite) in Ceylon. Glaciers of Kabru, Pandim, etc. Salts of Sambhar Lake in Rajputana, and 'Reh' from Aligarh in North-Western Provinces. Analysis of Dolomite from Salt-range, Punjab.

Part 2 (out of print).—Oil near Moghal Kot, in Sheráni country, Suleiman Hills. Mineral Oil from Suleiman Hills. Geology of Lushai Hills. Coal-fields in Northern Shan States. Reported Namséka Ruby-Mine in Mainglôn State. Tourmaline (Schorl) Mines in Mainglôn State. Salt-range near Bawgyo, Thibaw State.

Part 3 (out of print).—Boring in Daltonganj Coal-field, Palamow. Death of Dr. P. Martin Duncan. Pyroxenic varieties of Gneiss and Scapolite-bearing Rocks.

Part 4 (out of print).—Mammalian Bones from Mongolia. Darjeeling Coal Exploration. Geology and Mineral Resources of Sikkim. Rocks from the Salt-range, Punjab.

Vol. XXV, 1892.

Part 1 (out of print).—Annual report for 1891. Geology of Thal Chotiáli and part of Mari country. Petrological Notes on Boulder-bed of Salt-range, Punjab. Sub-recent and Recent Deposits of valley plains of Quetta, Pishin, and Dashti-i-Bedalot; with appendices on Chamans of Quetta; and Artesian water-supply of Quetta and Pishin.

Part 2 (out of print).—Geology of Saféd Kôh. Jherria Coal-field.

Part 3 (out of print).—Locality of Indian Tscheffkinite. Geological Sketch of country north of Bhamo. Economic resources of Amber and Jade mines area in Upper Burma. Iron-ores and Iron industries of Salem District. Riebeckite in India. Coal on Great Tenasserim River, Lower Burma.

Part 4 (out of print).—Oil Springs at Mogal Kot in Shirani Hills. Mineral Oil from Suleiman Hills. New Amber-like Resin in Burma. Triassic Deposits of Salt-range.

Vol. XXVI, 1893.

Part 1 (out of print).—Annual report for 1892. Central Himalayas. Jadeite in Upper Burma. Burmite, new Fossil Resin from Upper Burma. Prospecting Operations, Mergui District, 1891-92.

Part 2 (out of print)—Earthquake in Baluchistan of 20th December 1892. Burmite, new amber-like fossils from Upper Burma. Alluvial deposits and Subterranean water-supply of Rangoon.

Part 3 (out of print).—Geology of Sherani Hills. Carboniferous Fossils from Tenasserim. Boring at Chandernagore. Granite in Tavoy and Mergui.

Part 4 (out of print).—Geology of country between Chappar Rift and Harnai in Baluchistan. Geology of part of Tenasserim Valley with special reference to Tendau-Kamapying Coal-field. Magnetite containing Manganese and Alumina. Hislopite.

Vol. XXVII, 1894.

Part 1 (out of print).—Annual report for 1893. Bhaganwala Coal-field, Salt-range, Punjab.

Part 2 (out of print).—Petroleum from Burma. Singareni Coal-field, Hyderabad (Deccan). Gohna Landslip, Garhwal.

Part 3 (out of print).—Cambrian Formation of Eastern Salt-range Giridih (Karharbari) Coal-fields. Chipped (?) Flints in Upper Miocene of Burma. Velates Schmideliana, Chemn., and Provelates grandis, Sow. sp., in Tertiary Formation of India and Burma.

Part 4 (out of print).—Geology of Wuntho in Upper Burma. Echinoids from Upper Cretaceous System of Baluchistan. Highly Phosphatic Mica Periodotites intrusive in Lower Gondwana Rocks of Bengal. Mica-Hypersthene-Hornblende Periodotite in Bengal.

Vol. XXVIII, 1895.

Part 1.—Annual report for 1894. Cretaceous Formation of Pondicherry. Early allusion to Barren Island. Bibliography of Barren Island and Narcondam from 1884 to 1894.

Part 2 (out of print).—Cretaceous Rocks of Southern India and geographical conditions during later cretaceous times. Experimental Boring for Petroleum at Sukkur from October 1893 to March 1895. Tertiary system in Burma.

Part 3 (out of print).—Jadeite and other rocks, from Tammaw in Upper Burma. Geology of Tochi Valley. Lower Gondwanas in Argentina.

Part 4 (out of print).—Igneous Rocks of Giridih (Kurhurbaree) Coal-field and their Contact Effects. Vindhyan system south of Sone and their relation to so-called Lower Vindhyan. Lower Vindhyan area of Sone Valley. Tertiary system in Burma.

Vol. XXIX, 1896.

Part 1 (out of print).—Annual report for 1895. Acicular inclusions in Indian Garnets. Origin and Growth of Garnets and of their Micropegmatitic intergrowths in Pyroxenic rocks.

Part 2 (out of print).—Ultra-basic rocks and derived minerals of Chalk (Magnesite) hills, and other localities near Salem, Madras. Corundum localities in Salem and Coimbatore districts, Madras. Corundum and Kyanite in Manbhum district, Bengal. Ancient Geography of "Gondwana-land." Notes.

Part 3.—Igneous Rocks from the Tochi Valley. Notes.

Part 4 (out of print).—Steatite mines, Minbu district, Burma. Lower Vindhyan (Sub-Kaimur) area of Sone Valley, Rewah. Notes.

VOL. XXX, 1897.

Part 1.—Annual report for 1896. Norite and associated Basic Dykes and Lava-flows in Southern India. Genus Vertebraria. On Glossopteris and Vertebraria.

Part 2.—Cretaceous Deposits of Pondicherri. Notes.

Part 3 (out of print).—Flow structure in igneous dyke. Olivine-norite dykes at Coonoor. Excavations for corundum near Palakod, Salem District. Occurrence of coal at Palana in Bikaner. Geological specimens collected by Afghan-Baluch Boundary Commission of 1896.

Part 4.—Nemalite from Afghanistan. Quartz-barytes rock in Salem district, Madras Presidency. Worn femur of Hippopotamus irravadicus, Caut. and Falc., from Lower Pliocene of Burma. Supposed coal at Jaintia, Baxa Duars. Percussion Figures on micas. Notes.

VOL. XXXI, 1904.

Part 1 (out of print).—Prefatory Notice. Copper-ore near Komai, Darjeeling district. Zewan beds in Vihi district, Kashmir. Coal deposits of Isa Khel, Mianwali district, Punjab. Um-Rileng coal-beds, Assam. Sapphirine-bearing rock from Vizagapatam District. Miscellaneous Notes. Assays.

Part 2 (out of print).—Lt.-Genl. C. A. McMahon. Cyclobus Haydeni Diener. Auriferous Occurrences of Chota Nagpur, Bengal. On the feasibility of introducing modern methods of Coke-making at East Indian Railway Collieries, with supplementary note by Director, Geological Survey of India. Miscellaneous Notes.

Part 3 (out of print).—Upper Palæozoic formations of Eurasia. Glaciation and History of Sind Valley. Halorites in Trias of Baluchistan. Geology and Mineral Resources of Mayurbhanj. Miscellaneous Notes.

Part 4 (out of print).—Geology of Upper Assam. Auriferous Occurrences of Assam. Curious occurrence of Scapolite from Madras Presidency. Miscellaneous Notes. Index.

VOL. XXXII, 1905.

Part 1.—Review of Mineral production of India during 1898—1903.

Part 2 (out of print).—General report, April 1903 to December 1904. Geology of Provinces of Tsang and Ü in Tibet. Bauxite in India. Miscellaneous Notes.

Part 3 (out of print).—Anthracolithic Fauna from Subansiri Gorge, Assam. Elephas Antiquus (Namadicus) in Godavari Alluvium. Triassic Fauna of Tropites-Limestone of Byans. Amblygonite in Kashmir. Miscellaneous Notes.

Part 4.—Obituary notices of H. B. Medlicott and W. T. Blanford. Kangra Earthquake of 4th April 1905. Index to Volume XXXII.

VOL. XXXIII, 1906.

Part 1 (out of print).—Mineral Production of India during 1904. Pleistocene Movement in Indian Peninsula. Recent Changes in Course of Nam-tu River, Northern Shan States. Natural Bridge in Gokteik Gorge. Geology and Mineral Resources of Narnaul District (Patiala State). Miscellaneous Notes.

Part 2.—General report for 1905. Lashio Coal-field, Northern Shan States. Namma, Mansang and Man-se-le Coal-fields, Northern Shan States, Burma. Miscellaneous Notes.

Part 3 (out of print).—Petrology and Manganese-ore Deposits of Sausar Tahsil, Chhindwara district, Central Provinces. Geology of part of valley of Kanhan River in Nagpur and Chhindwara districts, Central Provinces. Manganite from Sandur Hills. Miscellaneous Notes.

Part 4 (out of print).—Composition and Quality of Indian Coals. Classification of the Vindhyan System. Geology of State of Panna with reference to the Diamond-bearing Deposits. Index to Volume XXXIII.

VOL. XXXIV, 1906.

Part 1.—*Fossils from Halorites Limestone of Bambanag Cliff, Kumaon. Upper Triassic Fauna from Pishin District, Baluchistan. Geology of portion of Bhutan.* Coal Occurrences in *Foot-hills of Bhutan.* Dandli Coal-field: Coal outcrops in Kotli Tehsil of Jammu State. Miscellaneous Notes.

Part 2 (out of print).—Mineral production of India during 1905. Nummulites Douvillei, with remarks on Zonal Distribution of Indian Nummulites. Auriferous Tracts in Southern India. Abandonment of Collieries at Warora, Central Provinces. Miscellaneous Notes.

Part 3.—Explosion Craters in Lower Chindwin District, Burma. Lavas of Pavagad Hill. Gibbsite with Manganese-ore from Talevadi, Belgaum district, and Gibbsite from Bhekowli, Satara District. Classification of Tertiary System in Sind with reference to Zonal distribution of Eocene Echinoidea.

Part 4 (out of print).—Jaipur and Nazira Coal-fields, Upper Assam. Makum Coal-fields between Tirap and Namdang Streams. Kobat Anticline, near Seiktein, Myingyan district, Upper Burma. Asymmetry of Yenangyat-Singu Anticline, Upper Burma. Northern part of Gwegyo Anticline, Myingyan District, Upper Burma. Breynia Multituberculata, from Nari of Baluchistan and Sind. Index to Volume XXXIV.

VOL. XXXV, 1907.

Part 1 (out of print).—General report for 1906. Orthophragmina and Lepidocyclina in Nummulitic Series. Meteoric Shower of 22nd October 1903 at Dokachi and neighbourhood, Dacca district.

Part 2.—Indian Aerolites. Brine-wells at Bawgyo, Northern Shan States. Gold-bearing Deposits of Loi Twang Shan States. Physa Prinsepii in Maestrichtian strata of Baluchistan. Miscellaneous Notes.

Part 3.—Preliminary survey of certain Glaciers in North-West Himalaya. A.—Notes on certain Glaciers in North-West Kashmir.

Part 4.—Preliminary survey of certain Glaciers in North-West Himalaya. B.—Notes on certain Glaciers in Lahaul. C.—Notes on certain Glaciers in Kumaon. Index to Volume XXXV.

VOL. XXXVI, 1907-08.

Part 1 (out of print).—Petrological Study of Rocks from hill tracts, Vizagapatam district, Madras Presidency. Nepheline Syenites from hill tracts, Vizagapatam district, Madras Presidency. Stratigraphical Position of Gangamopteris Beds of Kashmir. Volcanic outburst of Late Tertiary Age in South Hsenwi, N. Shan States. New suidæ from Bugti Hills, Baluchistan. Permo-Carboniferous Plants from Kashmir.

Part 2.—Mineral Production of India during 1906. Ammonites of Bagh Beds. Miscellaneous Notes.

Part 3 (out of print).—Marine fossils in Yenangyaung oil-field, Upper Burma. Freshwater shells of genus Batissa in Yenangyaung oil-field, Upper Burma. New Species of Dendrophyllia from Upper Miocene of Burma. Structure and age of Taungtha Hills, Myingyan district, Upper Burma. Fossils from Sedimentary rocks of Oman (Arabia). Rubies in Kachin hills, Upper Burma. Cretaceous Orbitoides of India. Two Calcutta Earthquakes of 1906. Miscellaneous Notes.

Part 4 (out of print).—Pseudo-Fucoids from Pab sandstones at Fort Munro, and from Vindhyan series. Jadeite in Kachin Hills, Upper Burma. Wetchok-Yedwet Pegu outcrop, Magwe district, Upper Burma. Group of Manganates, comprising Hollandite, Psilomelane and Coronadite. Occurrence of Wolfram in Nagpur district, Central Provinces. Miscellaneous Notes. Index to Volume XXXVI.

VOL. XXXVII, 1908-09.

Part 1 (out of print).—General report for 1907. Mineral Production of India during 1907. Occurrence of striated boulders in Blaini formation of Simla. Miscellaneous Notes.

Part 2.—Tertiary and Post-Tertiary Freshwater Deposits of Baluchistan and Sind. Geology and Mineral Resources of Rajpipla State. Suitability of sands in Rajmahal Hills for glass manufacture. Three new Manganese-bearing minerals :—Vredenburgite, Sitaparite and Juddite. Laterites from Central Provinces. Miscellaneous Notes.

Part 3 (out of print).—Southern part of Gwegyo Hills, including Payagyigon-Ngashandaung Oil-field. Silver-lead mines of Bawdwin, Northern Shan States. Mud volcanoes of Arakan Coast, Burma.

Part 4.—Gypsum Deposits in Hamirpur district, United Provinces. Gondwanas and related marine sedimentary system of Kashmir. Miscellaneous Notes. Index to Volume XXXVII.

VOL. XXXVIII, 1909-10.

Part 1.—General report for 1908. Mineral Production of India during 1908.

Part 2 (out of print).—Ostrea latimarginata in "Yenangyaung stage" of Burma. China-clay and Fire-clay deposits in Rajmahal Hills. Coal at Gilhurria in Rajmahal hills. Pegu Inlier at Ondwe, Magwe district, Upper Burma. Salt Deposits of Rajputana. Miscellaneous Notes.

Part 3.—Geology of Sarawan, Jhalawan, Mekran and the State of Las Bela. Hippurite-bearing Limestone in Seistan and Geology of adjoining region. Fusulinidæ from Afghanistan. Miscellaneous Notes.

Part 4.—Geology and Prospects of Oil in Western Prome and Kama, Lower Burma (including Namayan, Padaung, Taungbogyi and Zialag). Recorrelation of Pegu system in Burma with notes on Horizon of Oil-bearing Strata (including Geology of Padaukpin, Banbyin and Aukmanein). Fossil Fish Teeth from Pegu system, Burma. Northern part of Yenangyat Oil-field. Iron Ores of Chanda, Central Provinces. Geology of Aden Hinterland. Petrological Notes on rocks near Aden. Upper Jurassic Fossils near Aden. Miscellaneous Notes. Index to Volume XXXVIII.

VOL. XXXIX, 1910.

Quinquennial Review of Mineral Production of India during 1904 to 1908.

VOL. XL, 1910.

Part 1.—Pre-Carboniferous Life-Provinces. Lakes of Salt Range in the Punjab. Preliminary survey of certain Glaciers in Himalaya. D.—Notes on certain glaciers in Sikkim. New Mammalian Genera and Species from Tertiaries of India.

Part 2 (out of print).—General Report for 1909. Mineral Production of India during 1909.

Part 3.—Revised Classification of Tertiary Freshwater Deposits of India. Revision of Silurian Trias Sequence in Kashmir. Fenestella-bearing beds in Kashmir.

Part 4.—Alum Shale and Alum Manufacture, Kalabagh, Mianwali district, Punjab. Coal-fields in North-Eastern Assam. Sedimentary Deposition of Oil. Miscellaneous Notes. Index to Volume XL.

VOL. XLI, 1911-12.

Part 1.—Age and continuation in Depth of Manganese-ores of Nagpur-Balaghat Area, Central Provinces. Manganese-ore deposits of Gangpur State, Bengal, and Distribution of Gondite Series in India. Baluchistan Earthquake of 21st October 1909. Identity of Ostrea Promensis, Noetling, from Pegu System of Burma and Ostrea Digitalina, Eichwald, from Miocene of Europe. Mr. T. R. Blyth. Miscellaneous Notes.

Part 2.—General Report for 1910. Devonian Fossils from Chitral, Persia, Afghanistan and Himalayas. Sections in Pir Panjal Range and Sind Valley, Kashmir.

Part 3.—Mineral Production of India during 1910. Samarskite and other minerals in Nellore District, Madras Presidency. Coal in Namchik Valley, Upper Assam. Miscellaneous Notes.

Part 4.—Pegu-Eocene Succession in Minbu District near Ngape. Geology of Henzada District, Burma. Geology of Lonar Lake, with note on Lonar Soda Deposit. International Geological Congress of Stockholm. Miscellaneous Notes. Index to Volume XLI.

VOL. XLII, 1912.

Part 1.—Survival of Miocene Oyster in Recent Seas. Silurian Fossils from Kashmir. Blödite from Salt Range. Gold-bearing Deposits of Mong Long, Hsipaw State, Northern Shan States, Burma. Steatite Deposits, Idar State. Miscellaneous Note.

Part 2.—General Report for 1911. Dicotyledonous Leaves from Coal Measures of Assam. Poting Glacier, Kumaon, Himalaya, June 1911. Miscellaneous Notes.

Part 3.—Mineral Production of India during 1911. Kodurite Series.

Part 4.—Geological Reconnaissance through Dehong Valley, being Geological Results of Abor Expedition, 1911-12. Traverse Across the Naga Hills of Assam. Indian Aerolites. Miscellaneous Notes.

VOL. XLIII, 1913.

Part 1 (out of print).—General Report for 1912. Garnet as a Geological Barometer. Wolframite in Tavoy District, Lower Burma. Miscellaneous Notes.

Part 2 (out of print).—Mineral Production of India during 1912. Relationship of the Himalaya to the Indo-Gangetic Plain and the Indian Peninsula. Hambergite from Kashmir.

Part 3.—Contributions to the geology of the Province of Yünnan in Western China: I.—Bhamo-Têng Yüeh Area. II.—Petrology of Volcanic Rocks of Têng-Yüeh District. The Kirna Hills. Banswal Aerolite.

Part 4.—Gold-bearing Alluvium of Chindwin River and Tributaries. Correlation of Siwalik with Mammal Horizons of Europe. Contributions to the Geology of the Province of Yünnan in Western China: III.—Stratigraphy of Ordovician and Silurian Beds of Western Yünnan, with Provisional Palæontological Determinations. Notes on "Camarocrinus Asiaticus" from Burma.

VOL. XLIV, 1914.

Part 1.—General Report for 1913. Carbonaceous Aërolite from Rajputana. Nummulite as Zone Fossils, with description of some Burmese species.

Part 2.—Contributions to the Geology of the Province of Yünnan in Western China: IV.—Country around Yünnan Fu. Dyke of white Trap from Pench Valley Coal-field, Chhindwara District, Central Provinces. Mineral concessions during 1913.

Part 3.—Coal-seams near Yaw River, Pakokku District, Upper Burma. The Monazite Sands of Travancore. Lower Cretaceous Fauna from Himalayan Gieumal Sandstone together with description of a few fossils from Chikkim series. Indarctos salmontanus Pilgrim. Future Beheading of Son and Rer Rivers by Hasdo.

Part 4.—Salt Deposits of Cis-Indus Salt Range. Teeth referable to Lower Siwalik Creodont genus 'Dissopsalis' Pilgrim. Glaciers of Dhauli and Lissar Valleys, Kumaon, Himalaya, September 1912. Miscellaneous Notes.

VOL. XLV, 1915.

Part 1.—New Siwalik Primates. Brachiopoda of Namyau Beds of Burma. Miscellaneous Note.

Part 2.—General Report for 1914. Note on Sivaelurus and Paramachaerodus.

Part 3.—Mineral Production of India during 1914. Three New Indian Meteorites. Kuttippuram, Shupiyan and Kamsagar. Dentition of Tragulid Genus Dorcabune, Hematite Crystals of Corundiform Habit from Kajlidongri, Central India.

Part 4.—Geology of country near Ngahlaingdwin. Geology of Chitral, Gilgit and Pamirs.

VOL. XLVI, 1915.

Quinquennial Review of Mineral Production of India for 1909 to 1913.

VOL. XLVII, 1916.

Part 1.—General Report for 1915. Eocene Mammals from Burma. Miscellaneous Notes.

Part 2.—The Deccan Trap Flows of Linga, Chhindwara District, Central Provinces. Iron Ore Deposits of Twinngé, Northern Shan States.

Part 3.—Obituary: R. C. Burton. Mineral Production of India during 1915. Flemingostrea, an eastern group of Upper Cretaceous and Eocene Ostreidæ, with descriptions of two new species.

Part 4.—Contributions to the Geology of the Province of Yünnan in Western China: 5.—Geology of parts of the Salween and Mekong Valleys. A fossil wood from Burma. The Visuni and Ekh Khera Aerolites.

VOL. XLVIII, 1917.

Part 1.—General Report for 1916. A revised classification of the Gondwana System.

Part 2.—Mineral Production of India during 1916. Mammal collections from Basal Beds of Siwaliks.

Part 3.—Crystallography and Nomenclature of Hollandite. Geology and Ore Deposits of Bawdwin Mines. Miscellaneous Notes.

Part 4.—Biana-Lalsot Hills in Eastern Rajputana. Origin of the Laterite of Seoni, Central Provinces.

VOL. XLIX, 1918-19.

Part 1.—General Report for 1917. Cassiterite Deposits of Tavoy. Les Echinides des "Bagh Beds."

Part 2.—Mineral Production of India during 1917. Support of Mountains of Central Asia.

Part 3.—Structure and Stratigraphy in North-West Punjab. Aquamarine Mines of Daso, Baltistan. Srimangal Earthquake of July 8th, 1918.

Part 4.—Possible Occurrence of Petroleum in Jammu Province: Preliminary Note on the Nar-Budhan Dome, of Kotli Tehsil in the Punch Valley. Submerged Forests at Bombay. Infra-Trappeans and Silicified Lava from Hyderabad, S. India.

VOL. L, 1919.

Part 1.—General Report for 1918. Potash Salts of Punjab Salt Range and Kohat. Origin and History of Rock-salt Deposits of Punjab and Kohat.

Part 2.—Tungsten and Tin in Burma. Inclination of Thrust-plane between Siwalik and Murree zone near Kotli, Jammu. Two New Fossil Localities in Garo Hills. Sanni Sulphur Mine. Miscellaneous Notes.

Part 3 (out of print).—Mineral Production of India during 1918. Gastropoda Fauna of Old Lake-beds in Upper Burma. Galena Deposits of North-Eastern Putao.

Part 4 (out of print).—Pitchblende, Monazite and other minerals from Pichhli, Gaya district, Bihar and Orissa. Natural Gas in Bituminous Salt from Kohat. Mineral Resources of Central Provinces. Miscellaneous Notes.

VOL. LI, 1920-21.

Part 1.—General Report for 1919. Pseudo-crystals of Graphite from Travancore. Mineral related to Xenotime from Manbhum District, Bihar and Orissa Province. Coal Seams of Foot-Hills of the Arakan Yoma, between Letpan Yaw in Pakokku and Ngapè in Minbu, Upper Burma. Observations on "Physa Prinsepii," Sowerby and on a Clionid Sponge that burrowed in its shell.

Part 2.—Classification of fossil Cypræidæ. Sulphur near the confluence of the Greater Zab with the Tigris, Mesopotamia. Miscellaneous Notes.

Part 3.—Mineral Production of India during 1919. Results of a Revision of Dr. Noetling's Second Monograph on the Tertiary Fauna of Burma. Marine Fossils collected by Mr. Pinfold in the Garo Hills.

Part 4.—Illustrated comparative Diagnoses of Fossil Terebridæ from Burma. Indian Fossil Viviparæ. New fossil Unionid from the Intertrappean beds of Peninsular India. Unionidæ from the Miocene of Burma.

VOL. LII, 1921.

Quinquennial Review of Mineral Production of India for 1914—1918.

VOL. LIII, 1921.

Part 1.—General Report for 1920. Antimony deposit of Thabyu, Amherst district. Antimony deposits of Southern Shan States. Geology and Mineral Resources of Eastern Persia. Miscellaneous Notes.

Part 2.—Comparative Diagnoses of Pleurotomidæ from Tertiary Formation of Burma. Comparative Diagnoses of Conidæ and Cancellariidæ from Tertiary of Burma. Stratigraphy, Fossils and Geological Relationships of Lameta Beds of Jubbulpore. Rocks near Lameta Ghat (Jubbulpore District).

Part 3 (out of print).—Obituary: Frederick Richmond Mallet. Mineral Production of India during 1920. Mineral Resources of Bihar and Orissa.

Part 4.—Stratigraphy of the Singu-Yenangyat Area. Analysis of Singu Fauna. Sulphur Deposits of Southern Persia. A Zone-Fossil from Burma: Ampullina (Megatylotus) Birmanica.

VOL. LIV, 1922.

Part 1.—General Report for 1921. Contributions to the Geology of the Province of Yünnan in Western China: 6.—Traverses between Tali Fu and Yunnan Fu. Geology of Takki Zam Valley, and Kaniguram-Makin Area, Waziristan. Geology of Thayetmyo and neighbourhood, including Padaukbin. Bitumen in Bombay Island.

Part 2.—Mineral Production of India during 1921. Iron Ores of Singhbhum and Orissa. Geological Results of Mount Everest Reconnaissance Expedition. Northern Extension of Wolfram-bearing Zone in Burma. Miscellaneous Note.

Part 3.—Obituary: Rupert William Palmer. Indian Tertiary Gastropoda, IV.—Olividæ, Harpidæ, Marginellidæ, Volutidæ and Mitridæ, with comparative diagnoses of new species, Structure of Cuticle in Glossopteris angustifolia Brongn. Revision of some Fossil Balanomorph Barnacles from India and the East Indian Archipelago. Contributions to the Geology of the Province of Yunnan in Western China: 7.—Reconnaissance Surveys between Shunning Fu, Chingtung Ting and Tali Fu. 8.—Traverse down Yang-tze-chiang Valley from Chin-chiang-kai to Hui-li-Chou. Boulder Beds beneath Utatur State, Trichinopoly District. Miscellaneous Notes.

Part 4.—Geology of Western Jaipur. Geological Traverses from Assam to Myitkyina through Hukong Valley: Myitkyina to Northern Putao: and Myitkyina to Chinese Frontier. Oligocene Echinoidea collected by Rao Bahadur S. Sethu Rama Rau in Burma. Mineral Resources of Kolhapur State. Kunghka and Manmaklang Iron Ore Deposits, Northern Shan States, Burma.

VOL. LV, 1923-24.

Part 1.—General Report for 1922. Indian Tertiary Gastropoda, No. 5, Fusidæ, Turbinellidæ, Chrysodomidæ, Strepturidæ, Buccinidæ, Nassidæ, Columbellidæ, with short diagnoses of new species. Geological Interpretation of some Recent Geodetic Investigations (being a second Appendix to the Memoir on the structure of the Himalayas and of the Gangetic Plain as elucidated by Geodetic Observations in India).

Part 2.—Obituary: Ernest (Watson) Vredenburg. Fossil Molluscs from Oil-Measures of Dawna Hills, Tenasserim. Armoured Dinosaur from Lameta Beds of Jubbulpore. Fossil forms of Placuna. Phylogeny of some Turbinellidæ. Recent Falls of Aerolites in India. Geology of part of Khasi and Jaintia Hills, Assam.

Part 3.—Mineral Production of India during 1922. Lignitic Coal-fields in Karewa formation of Kashmir Valley. Basic and Ultra-Basic Members of the Charnockite Series in the Central Provinces. China Clay of Karalgi, Khanapur, Belgaum District.

Part 4.—Obituary: Henry Hubert Hayden. Oil Shales of Eastern Amherst, Burma, with a Sketch of Geology of Neighbourhood. Provisional list of Palæozoic and Mesozoic Fossils collected by Dr. Coggin Brown in Yünnan. Fall of three Meteoric Irons in Rajputana on 20th May 1921. Miscellaneous Note.

VOL. LVI, 1924-25.

Part 1.—General Report for 1923. Mineral Deposits of Burma.

Part 2.—Mineral Production of India during 1923. Soda rocks of Rajputana.

Part 3.—Gyrolite and Okenite from Bombay. Freshwater Fish from oil-measures of Dawna Hills. Fossil Ampullariid from Poonch, Kashmir. Calcareous Alga belonging to Triploporelleæ (Dasycladaceæ) from Tertiary of India. Froth Flotation of Indian Coals. Submarine Mud Eruptions off Arakan Coast, Burma. Cretaceous Fossils from Afghanistan and Khorasan.

Part 4.—Merua Meteorite. Stegodon Ganesa in Outer Siwaliks of Jammu. Land and Fresh water Fossil Molluscs from Karewas of Kashmir. Burmese Lignites from Namma, Lashio and Pauk. Maurypur Salt Works.

VOL. LVII, 1925.

Quinquennial Review of Mineral Production of India for 1919-1923. Price 5 Rs. 10 As.

VOL. LVIII, 1925-26.

Part 1.—General Report for 1924. Fossil Tree in Panchet Series of Lower Gondwanas near Asansol, with Palæontological Description.

Part 2.—Obituary: Francis William Walker. Possibilities of finding concealed coal-field at a workable depth in Bombay Presidency. Basaltic Lavas penetrated by deep boring for coal at Bhusawal, Bombay Presidency.

Part 3.—Mineral Production of India during 1924. Enstatite-Augite Series of Pyroxenes. Constitution of the Glauconite and Celadonite. Palagonite-bearing Dolerite from Nagpur.

Part 4.—Fossiles Crétacés de l'Afghanistan. Fossiles du Kashmir et des Pamirs. Additions and Corrections to Vredenburg's Classification of the Cypræidæ. Petrology of Rocks from Girnar and Osham Hills, Kathiawar, India.

VOL. LIX, 1926.

Part 1.—General Report for 1925. Foraminifera of parts of Western India.

Part 2.—Sampling Operations in Pench Valley Coal-field. Composition of some Indian Garnets. Geology of Andaman and Nicobar Islands, with special reference to Middle Andaman Island. Occurrence of Cryptohalite. Remarks on Carter's Genus Conulites.

Part 3.—Mineral Production of India during 1925. Metamorphic Rocks and Intrusive Granite of Chhota Udepur State. Indian Species of Conoclypeus.

Part 4.—Low-Phosphorus Coking Coal in Giridih Coal-field. Distribution of Gault in India. Age of so-called Danian Fauna from Tibet. Bauxite on Korlapat Hill, Kalahandi State, Bihar and Orissa.

VOL. LX, 1927-28.

Part 1.—General Report for 1926. Six Recent Indian Aerolites.

Part 2.—Gas Eruption on Ramri Island, off Aracan Coast of Burma, in July, 1926. Oil Indications at Drigh Road near Karachi. Lower Canine of Tetraconodon. Geology of Bundi State, Rajputana.

Part 3.—Mineral Production of India during 1926. Geological Traverse in Yunaslin Valley. Ambala Boring of 1926-27. Indian Unionidæ.

Part 4.—Relationship between Specific Gravity and Ash Contents of Coals of Korea and Bokaro Coals as Colloid Systems. Contact of Basalt with coal-seam in the Isle of Skye, Scotland. Comparison with Indian examples. Barakar-Ironstone Boundary near Begunia, Raniganj Coal-field. Raniganj-Panchet Boundary near Asansol, Raniganj Coal-field. Permo-Carboniferous Marine Fauna from Umaria Coal-field. Geology of Umaria Coal-field, Rewah State, Central India. Composition and Nomenclature of Chlorophæite and Palagonite, and on Chlorophæite Series. Miscellaneous Notes.

VOL. LXI, 1928-29.

Part 1.—General Report for 1927. Actinodon risinensis in Lower Gondwanas of Vihi district, Kashmir. Miscellaneous Note: Further Note on Nomenclature of Hollandite.

Part 2.—Contribution to Geology of Punjab Salt Range. Iron Ore Deposits of Northern Shan States. Lower Canine of Indian Species of Conohyus. Miscellaneous Note: Leucopyrite from Kodarma.

Part 3.—Mineral Production of India during 1927. Note on Coking Tests with Gondwana Coals. Zinc-Spinel, from Southern India. New Indian Meteorite: Lua Fall. Miscellaneous Note: Löllingite from Hazaribagh District.

Part 4.—Erratics of the Punjab. Cretaceous Dinosaurs of Trichinopoly District, and Rocks associated with them. Orbitolinæ from Tibet. Joya Mair Dome Fold, near Chakwal, Jhelum District, Punjab. Occurrence of Allophane at Tikak, Assam. Miscellaneous Note: Australian Species of Genus *Gisortia*.

VOL. LXII, 1929-30.

Part 1.—General Report for 1928. Miscellaneous Note: New Chromite Localities.

Part 2.—Obituary: Sivaran Sethu Rama Rau. Specific Gravity and Proximate Composition of Indian Vitrains. New Devonian Fossils from Burma. Rangoon Earthquakes of September and December 1927. Epicentre of North-West Himalayan Earthquake of 1st February 1929. Miscellaneous Notes: Indian Beryl, Atacamite in Bihar and Pyromorphite in Bhagalpur district, Bihar.

Part 3.—Mineral Production of India during 1928. Granophyric Trachyte from Salsette Island, Bombay. Coal Resources of Jharia Coal-field. Coal lost by Fires and Collapses in Indian Coal Mines.

Part 4.—Age of Aravalli Range. Lake's Rule for Angle of Overthrust, as applied to Himalayas. Permo-Carboniferous Succession in Warcha Valley, Western Salt Range, Punjab. Naoki (Hyderabad) Meteoric Shower of 29th September 1928. Miscellaneous Notes: Boring for water at Daryapur and Fossil Eggs at Yenangyoung.

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